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Waterways Experiment Station

Farmington, New Mexico, Sediment Impact Assessment

by Dinah N. McComas, Ronald R. Copeland

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Prepared for U.S. Army Engineer District, Albuquerque

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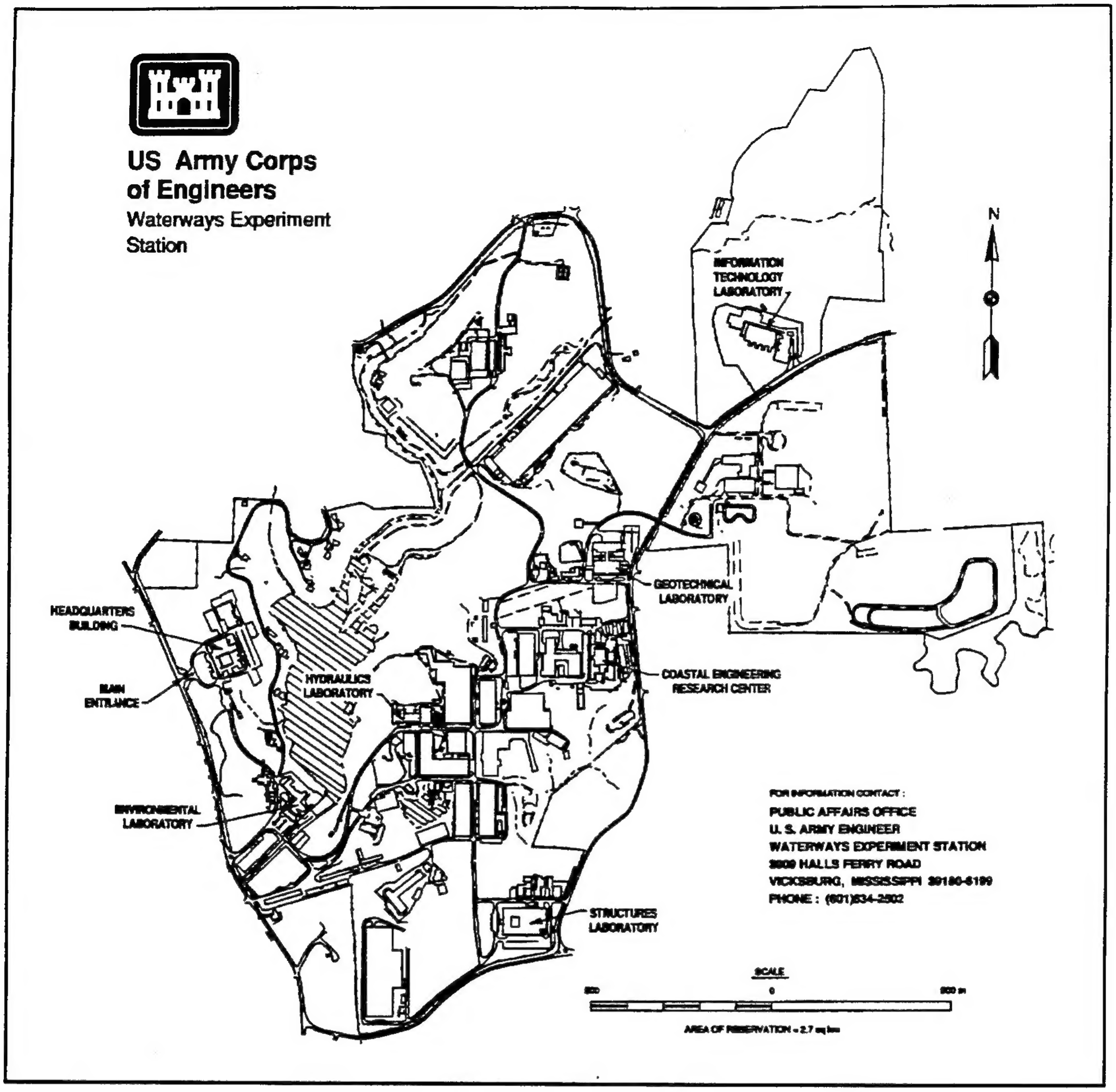

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Contents

Preface iv

Conversion Factors, Non-SI to SI Units of Measurement v

1—General 1

- Study Purpose 1
- Introduction 1
- General Watershed Characteristics 3

2—Animas River 4

- Channel Stability 4
- Sediment Transport Functions 6
- Bed-Material Sediment Yield 7
- Total Sediment Yield 8

3—La Plata River 10

- Channel Stability 10
- Bed-Material Sediment Yield 11
- Total Sediment Yield 12

4—San Juan River 13

- Channel Stability 13
- Bed-Material Sediment Yield 14
- Total Sediment Yield 14

5—Farmington Glade 15

- Channel Stability 15
- Bed-Material Sediment Yield 15
- Total Sediment Yield 16

6—Data Requirements for Detailed Sediment Study 17

7—Conclusions 18

References 19

Figures 1-38

SF 298

Preface

This sediment impact assessment for the San Juan River and tributaries, near Farmington, New Mexico, was conducted at the request of U.S. Army Engineer District, Albuquerque.

This investigation was conducted during the period April to September 1994 in the Hydraulics Laboratory of the U.S. Army Engineer Waterways Experiment Station (WES), under the direction of Mr. Frank A. Herrmann, Jr., Director of the Hydraulics Laboratory, Dr. Larry L. Daggett, Acting Chief of the Waterways Division, and Mr. Michael J. Trawle, Chief of the Math Modeling Branch. The project engineer for this study was Dr. Ronald R. Copeland, and the principal investigator was Mrs. Dinah N. McComas.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acre-feet	4,046.873	cubic meters
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
inches	2.54	centimeters
feet	0.3048	meters
miles (U.S. statute)	1.609347	kilometers
pounds (mass)	0.4535924	kilograms
pounds per square feet	47.88	Pascals
square miles	2.589998	square kilometers

1 General

Study Purpose

This sediment impact assessment is part of a reconnaissance-level planning study for the San Juan River and Tributaries for Farmington, New Mexico. The purpose of the sediment assessment is to identify the magnitude of any significant sediment problems associated with proposed flood control projects and to recommend appropriate sediment studies for the feasibility-level planning study. The sediment impact assessment provides an inventory of available sediment data and recommends data collection programs.

Introduction

The City of Farmington, New Mexico, is subject to flooding by four streams. These are the San Juan, Animas, and La Plata Rivers and Farmington Glade. The San Juan River Basin is centered on the Four Corners area of New Mexico, Figure 1. The San Juan River is the second largest tributary of the Colorado River and, at a point immediately below its confluence with the Animas River, has a drainage area of 7,240 square miles.[1] The Animas River is the largest tributary of the San Juan River and has a drainage area of 1,360 square miles (U.S. Army Engineer District (USAED), Sacramento, 1984). The Animas River flows along the eastern edge of Farmington, entering the San Juan River just south of the city. The La Plata River joins the San Juan River at the western edge of the city and has a drainage area of 583 square miles. Farmington Glade discharges into the San Juan River at Farmington between the confluences of the Animas and La Plata Rivers. This watershed is elongated, with a drainage area of 36.6 square miles, a length of 25 miles, and an average width of approximately 1.5 miles.[2]

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[1] A table of factors for converting Non-SI units of measurement to SI units is found on page v.

[2] U.S. Army Engineer District, Albuquerque. (1994). "San Juan River and tributaries reconnaissance study hydrologic analysis."

A sediment impact assessment for the San Juan, La Plata, and Animas Rivers through Farmington, and Farmington Glade, was requested by the Albuquerque District, Corps of Engineers. Flood control plans have not been developed so this study evaluates each of the four rivers' current conditions.

The purpose of a "sediment impact assessment" level sedimentation study is stated in EM 1110-2-4000 (Headquarters, U.S. Army Corps of Engineers, 1989). In summary, it is to identify potential sedimentation problems and to propose a plan of study if significant problems are indicated.

The sediment impact assessment consisted of a field reconnaissance, a review of previous sediment studies, and calculations of sediment yield. First a field reconnaissance was conducted to evaluate the stability of the existing channels. The field reconnaissance was conducted by Dr. Ronald R. Copeland and Mrs. Dinah N. McComas of U.S. Army Engineer Waterways Experiment Station (WES), and Mr. George Fish of Albuquerque District. All four rivers were photographed, especially at bridge crossings and confluences. Samples of the bed and bank sediments were taken for use in stability calculations. Results of this trip are detailed later in this report, individually by river. The review of previous studies provided estimates for total sediment yield. New calculations were performed to estimate bed-material sediment yield which is important for determining channel stability in existing and proposed river channels. The calculations for bed-material sediment yield were made using the SAM hydraulic design package (Thomas et al., in preparation). Hydraulic parameters of width, depth, slope, and velocity were calculated from district-provided HEC-2 or HEC-RAS output files. These parameters were used to calculate sediment rating curves. Sediment rating curves were integrated with the average annual flow duration curve and, if available, with the 50 percent chance exceedance and 1 percent chance exceedance flood balanced hydrographs, the peaks of which are listed in the following tabulation:

River	50 Percent Chance Exceedance Flood, cfs	1 Percent Chance Exceedance Flood, cfs
Animas River	5,940	20,700
La Plata River	1,370	9,020
Farmington Glade	453	3,365

A balanced hydrograph is a symmetrical, synthetic flood hydrograph in which duration of flow for a given discharge is obtained from a frequency duration curve. These calculations provided the average annual bed-material sediment yield, the 50 percent chance exceedance flood bed-material sediment yield, and the 1 percent chance exceedance flood bed-material sediment yield, each of which can be compared to historical data, or can be a gauge of the extent of a possible sedimentation problem if equilibrium is disturbed.

General Watershed Characteristics

The San Juan River Basin has been divided into hydrologic sub-basins. The Animas River, the La Plata River, and Farmington Glade are all within the Animas-La Plata sub-basin, which is located in the northeast quarter of the San Juan Basin (Figure 1). Within this sub-basin, most stream channels are well defined, well incised. This sub-basin contains areas of much higher elevation than most of the San Juan Basin.

Most of the streamflow in the San Juan Basin is provided by snowmelt from the mountainous northeastern area, resulting in high rates of runoff in May and June, medium flow in April and July, and low flow during the remainder of the year, except for occasional rainstorms (USAED, Sacramento, 1984).

In 1962, the Navajo Reservoir was completed on the San Juan River, about 47 river miles upstream from Farmington. This dam traps most of the sediment delivered from the upstream watershed. In 1963, the Lemon Reservoir was completed on the Florida River, a tributary of the Animas.

Even with the Navajo Reservoir, the San Juan River below Farmington has a higher sediment discharge rating curve than does the Animas River. This is attributed to the soils characteristics to the south and west of Farmington that have a higher yield potential than the soils in the Animas watershed. Coyote Wash and Canon Largo are tributaries which carry these more easily eroded sediments into the San Juan River (MacArthur and Wakeman 1983).

The Animas River was considered first because measured suspended sediment data were available. These data were used to select appropriate sediment transport functions for the Animas River. These same functions were then used to calculate sediment transport on the other streams.

2 Animas River

Channel Stability

During the limited field reconnaissance, no reaches of the Animas River with obvious aggradation or degradation trends were observed. It was concluded that the Animas River through Farmington was relatively stable under normal flow conditions. There was evidence of bank erosion and the formation of middle bars that are typical of coarse-bed alluvial rivers. There appeared to be an abundant supply of coarse gravels and cobbles in the river banks, and under major flood conditions extensive bank erosion could occur. In the places where the bed could be observed, it appeared to be well armored with cobbles and boulders.

Downstream of Browning Parkway Bridge, which is located about 4 miles upstream from the confluence with the San Juan River, Figure 2a, both sub-surface and surface gradations were determined from a middle bar. The gradations are shown in Figure 3. The surface gradation was determined using the Wolman (1954) method. One hundred pebbles were collected at approximately equal intervals longitudinally along the bar and measured in the field. The sub-surface sample was collected to a depth of about 1ft after the coarse surface layer was removed. A sieve analysis was performed to determine the sub-surface gradation. Upstream of Broadway Bridge, which is located about 2.25 miles upstream from the confluence with the San Juan River, Figure 2b, Wolman counts were taken on a chute and middle bar; these gradations are shown in Figure 3. The chute gradation was collected laterally across the stream but did not include the deepest part of the channel where rapid velocities prevented sampling. It can be assumed that the coarsest size classes were neglected due to the limited sample width. These bed gradations show that armoring of the stream bed is a major factor that influences the stability of the Animas River bed.

An analysis of critical shear stress can be useful in examining bed stability. The critical shear stress of the bed surface is determined in order to evaluate the stability of the armor layer. Critical shear stress is calculated using the following equation:

$$\tau_c = \Theta (\gamma_s - \gamma) d_{50} \tag{1}$$

where

τ_c = the critical shear stress.

Θ = the Shields Parameter = 0.047.

γ_s and γ = the specific weights of sediment and the fluid, respectively.

d_{50} = the median grain size of the bed material.

Calculated critical shear stresses are shown in the following tabulation:

Animas River at Farmington	
Location	**Calculated Critical Shear Stress, lb/ft^2**
Surface on middle bar downstream from Browning Drive	1.51
Surface on middle bar upstream from Broadway	2.54
Surface on chute upstream from Broadway	2.86

The HEC-2 backwater model prepared by the Albuquerque District was used to calculate average shear stress for the 50 percent chance exceedance and 1 percent chance exceedance flood peaks. A plot of shear stress for the two flood peaks is shown in Figure 4. This plot shows shear stresses ranging between 4.3 lb/ft^2 and 0.1 lb/ft^2 for the 1 percent chance exceedance flood and between 2.7 lb/ft^2 and 0.1 lb/ft^2 for the 50 percent chance exceedance flood. The critical shear stresses calculated above are exceeded at many locations during both floods according to the HEC-2 model.

The preceding analysis demonstrates the delicate nature of the Animas River bed. The calculations indicate that there will be significant movement of the channel bed during flood events. However, based on the field reconnaissance the existing channel appears to be stable, showing no general degradation trend. This is attributed primarily to a sufficient sediment supply from upstream. In addition, the large lateral and longitudinal variation in the surface bed gradation tends to stabilize the existing bed, while allowing for transport of sediment downstream for a wide range of flow conditions. It was apparent during the field reconnaissance that much larger material covered the bed in the channel where velocities were too great for sampling. These larger materials are apparently of sufficient size to armor the channel zone at lower flow conditions when sediment supply is limited. Any proposed flood control project should allow for continued delivery of coarse sediment from upstream and for variability in cross-section shape in order to maintain channel stability.

Critical bed control points can be identified from a plot of Froude Number versus distance (Figure 5). This plot shows six locations where the Froude number is calculated to be 1.0, indicating a critical depth control. Bed

gradations at these points should be significantly coarser, or there may be bedrock outcrops. The effect of any proposed modifications to the channel at these control points should be thoroughly investigated. A thorough inventory of the characteristics of the existing channel bed throughout the project reach is recommended for future studies. This inventory should be conducted at low water, identifying hard points and the size of armor layer material.

Hydraulic parameters that effect sediment transport include velocity and slope. Calculations indicate that these parameters vary significantly on the Animas River through Farmington for the 50 percent chance exceedance and 1 percent chance exceedance peak discharges (Figures 6 and 7). This variability is partially due to poor channel definition at several of the cross sections in the HEC-2 model. This variability makes it difficult to apply simple reach-averaged analysis techniques to the Animas River. If the proposed project significantly changes hydraulic parameters, then a detailed sedimentation study will be required. An adequate sediment analysis would require an HEC-6 numerical simulation that accounts for nonuniform water and sediment discharges.

Sediment Transport Functions

The measured sediment data from the Animas River gage at Farmington was used to evaluate sediment transport functions. Sediment transport functions are developed from data sets where the flow is essentially uniform, the bed material gradation is readily available, and the bed is not armored. On the Animas River, there is a wide variation in the bed material gradation laterally and longitudinally along the river bed. Since the calculated critical shear stress is exceeded at several locations during the 50 percent chance exceedance and 1 percent chance exceedance floods, it was assumed that the coarse surface layer would be mixed during flood conditions and that the subsurface bed gradation would be the most appropriate for calculating sediment transport. Einstein's (1950) recommendation was followed, and the finest 10 percent of the bed material sample was excluded from the sediment transport calculations. This put the division between wash load and bed-material load at 0.125 mm. This bed material gradation is shown in Figure 8. Average hydraulic variables were determined from the HEC-2 backwater model using the SAM hydraulic design package (Thomas et al., in preparation). SAM reads the HEC-2 Tape95 output and produces reach-length weighted averages for width, depth, slope, and velocity.

Sediment transport, calculated using several different transport functions, was compared to measured sediment data obtained between 1950 and 1992. The gage data were analyzed to determine if the Lemon Reservoir on the Florida River, completed in 1963, produced a shift in the sediment load curve. There was no apparent long-term trend, so the entire historical data set was used for this analysis. Calculated sediment transport is compared to the measured suspended load of grain sizes greater than 0.125 mm in Figure 9.

From this comparison four sediment transport functions were chosen for further consideration: Laursen-Copeland, Engelund-Hansen, Ackers-White, and Yang. The potential sediment transport at the peak of the 1 percent chance exceedance flood was plotted against grain size in Figure 10.. This figure indicates a discontinuity with the Yang function which was therefore excluded from further consideration. Also, the Engelund-Hansen function predicts the transport of much coarser material than either the Laursen-Copeland or Ackers-White functions.

Sediment transport calculations were compared to measured data for each size class (Figures 11 through 15). The fine-sand load (0.125 mm - 0.25 mm) was overestimated by all plotted functions, indicating that this size class is controlled more by supply than its presence in the bed and should therefore be considered as wash load. The boundary between wash load and bed-material load was therefore changed to 0.25 mm. This was the final lower size-class limit used to calculate bed-material sediment yield. This final bed gradation is shown in Figure 8. The Laursen-Copeland function produces an upper limit of expected sediment transport and yield, the Ackers-White a slightly less than median value, and the Engelund-Hansen an intermediate value. All three functions were used to calculate bed-material sediment transport and bed-material sediment yield for all the rivers in this study. A regression curve developed from historical measured data, using only the portion of the sediment load greater than 0.25 mm is shown in Figure 16. Regression curves at ± 2 standard deviations were also used to provide an envelope of possible sediment-rating curves within a 95 percent certainty range.

Bed-Material Sediment Yield

Bed-material sediment yield was calculated for the Animas River for the 50 percent chance exceedance and the 1 percent chance exceedance floods and for average annual flow. These calculations are for bed-material load only (material greater than 0.25 mm) and do not include the wash load that is contributed by the watershed. The 50 percent chance exceedance and 1 percent chance exceedance balanced hydrographs were developed by the Albuquerque District and are shown in Figures 17 and 18. The flow-duration curve for the average annual sediment yield was developed from the Animas River at Farmington gage from mean daily flow records between 1912 and 1992 and is shown in Figure 19. Sediment discharge rating curves were developed using three sediment transport functions, Laursen-Copeland, Engelund-Hansen, and Ackers-White (Figure 20), and the regression curve (Figure 16). Bed-material sediment yields, presented in the tabulation below, are given as a total volume in cubic yards and as a volume per unit of drainage area in acre-feet per square mile. Acre-ft/square mile was calculated assuming the total Animas drainage area of 1,360 square miles.

Calculated Bed-Material Sediment Yield Animas River at Farmington						
	Average-Annual		50 percent chance exceedance		1 percent chance exceedance	
Function	yd^3	acre-ft/ square mile	yd^3	acre-ft/ square mile	yd^3	acre-ft/ square mile
Laursen-Copeland	1,471,000	0.67	953,000	0.43	5,795,000	2.65
Engelund-Hansen	268,000	0.12	167,000	0.08	1,188,000	0.54
Ackers-White	70,500	0.03	46,100	0.02	274,000	0.12
Regression Curve	83,500	0.04	48,000	0.02	383,000	0.17
$+2\sigma$	2,097,000	0.96	1,205,000	0.55	9,629,000	4.39
-2σ	3,300	0.002	1,900	0.0009	15,300	0.007

The tabulation can be used to assess the predictive capability of the three transport functions. The yield calculated using the regression curve represents long-term average conditions. The Ackers-White function predicts yields closest to those calculated using the regression curve, but the Ackers-White function slightly under-predicts. Flood flows are more likely to produce sediment transport greater than the long-term average. The Laursen-Copeland function predicted sediment yields close to the 95 percent probable upper limit; the Engelund-Hansen function predicted intermediate values of bed-material sediment yield. It can be concluded that, on the Animas River, long-term sediment transport analysis may be best evaluated using the Ackers-White and Engelund-Hansen functions. However, flood hydrographs should be evaluated using the Engelund-Hansen and Laursen-Copeland functions. A more detailed sedimentation investigation should include a sensitivity study using more than one transport equation.

Based on the apparent stability of the existing channel, it can be assumed that the calculated bed-material sediment yield passes through Farmington without creating any significant aggradation or degradation problems. However, if the river regime is significantly altered, the magnitude of potential for degradation or aggradation problems is demonstrated by the calculated sediment yield.

Total Sediment Yield

Prediction of total sediment yield including both bed-material load and wash load is useful in predicting required sediment storage in reservoirs. Sources for the total sediment yield are watershed soil erosion, bank erosion, and channel bed erosion. MacArthur and Wakeman (1983) reported that the soils in the Animas drainage basin are susceptible to accelerated erosion even under normal rainfall conditions. They also reported that the composition of the channel banks in Farmington range from silty clays to coarse sands and

gravels and predicted that widespread erosion of these banks can be expected during major floods. In addition, localized erosion of the bed can be expected at constrictions and at channel structures such as bridge piers and bank protection.

MacArthur and Wakeman (1983) estimated the total (wash load and bed-material load) sediment yield for Animas River to be between 0.42 and 1.0 acre-ft/square mile per year at Farmington. The 0.42 acre-ft/square mile was based on average annual yields reported by the Upper Colorado Region Inter-Agency Group as an estimated "characteristic average suspended sediment yield." MacArthur and Wakeman stated that during an intense storm or high flow periods that yield could "easily be twice as large," thus the basis for the 1.0 acre-ft/square mile/year.

MacArthur and Wakeman (1983) also stated that according to studies reported by the Upper Colorado Region State-Federal Inter-Agency Group in 1971 and the U.S. Department of Interior in 1976, active watershed management programs were continuing to expand throughout the Animas watershed. These reports concluded that if these programs continued at their estimated rates, erosion and sediment yield would continue to decline slowly. However, long-term total suspended sediment measured data from the Animas at Farmington gage does not support this projection. These data extend from 1951 to 1992 and indicate no observable trend in sediment yield (Figure 21).

3 La Plata River

Channel Stability

The La Plata River through Farmington has a shallow channel with poorly defined banks and wide overbanks. Overflows spread out on both sides of the stream onto a flood plain about 1,000 ft wide (USAED, Sacramento, 1984). When overbank flow occurs, fine sand will deposit where the flow is slowed by vegetation. Summer cloudbursts produce the floods with highest discharges on the La Plata River, although flooding from snowmelt also occurs (USAED, Sacramento, 1984)

Bed material samples were taken at three locations on the La Plata River. Surface samples were collected upstream from Glade Hills Drive, located about 2.2 miles upstream from the confluence with the San Juan River, from both the vegetated overbank and a bar, Figures 22a and 22b. A substrate sample was collected from a bar at the gage between Glade Hills Drive and the confluence of the La Plata and San Juan Rivers, Figure 22c. The bed-material gradations are shown in Figure 23. Based on analysis of the measured sediment data on the Animas River, the division between bed-material load and wash load was assumed to be 0.25 mm for the La Plata River. The bed-material gradation used for the sediment yield calculations, Figure 23, was a normalized combination of the two bar samples and includes only material greater than 0.25 mm. The bed of the La Plata River is not as coarse as the bed of the Animas River.

Albuquerque District provided HEC-RAS input files for the La Plata River. Two of the hydraulic parameters that affect sediment transport, velocity and slope, are shown in Figures 24 and 25 plotted for the 50 percent chance exceedance and the 1 percent chance exceedance floods. These parameters vary significantly, making it difficult to apply simple reach-averaged analysis techniques to the La Plata River. This is partially attributed to poor channel definition in the model's cross sections. Reach-length weighted averaged hydraulic parameters cannot be calculated from HEC-RAS output with the SAM program. Therefore, choosing an average cross section for sediment yield calculations involved several steps. Examination of the profile for the La Plata River, Figure 26, showed cross sections 15 through 19 to represent a relatively stable reach. The hydraulic parameters of velocity,

hydraulic depth, and channel top width for this reach of the river were averaged for the range of discharges prescribed in the balanced hydrograph. Slope was determined directly from the energy grade line elevations at cross sections 15 and 19.

These averaged hydraulic parameters, from the reach between cross sections 15 and 19, were used as input to SAM. Sediment transport was calculated using the Ackers-White, Laursen-Copeland, and Engelund-Hansen sediment transport functions. The sediment transport rating curves developed for these three functions are shown in Figure 27. It was assumed that these functions would provide a range in the predicted sediment yield similar to that on the Animas River.

Bed-Material Sediment Yield

Bed-material sediment yield was calculated for the La Plata River for the 50 percent chance exceedance and 1 percent chance exceedance floods and for average annual flow. These calculations are for bed-material load only (material greater than 0.25 mm) and do not include the wash load that is contributed by the watershed. The 50 percent chance exceedance and 1 percent chance exceedance balanced hydrographs were developed by the Albuquerque District and are shown in Figures 28 and 29. The flow-duration curve for the average annual sediment yield was developed from the La Plata near Farmington gage from mean daily flows between 1938 and 1992, Figure 30. Bed-material sediment yields are presented in Table 1. Acre-ft/square mile was calculated assuming the total La Plata drainage area of 583 square miles. Bed material yields per square mile are less than those calculated for the Animas River. This is primarily due to the larger volume of runoff in the Animas River, although poor channel definition in the La Plata River cross sections from the HEC-RAS model may also result in some reduction in calculated sediment yield. Future sediment work would require more detailed channel cross sections.

Water surface profiles calculated using the HEC-RAS model indicated that water will pond behind the culverts which will reduce sediment transport potential through the reach. To assess the significance of the reduced sediment transport capacity in the ponded areas, sediment yield was calculated using the hydraulic parameters from cross section 3. These bed-material sediment yields are presented in Table 2. Cross section 3 is just upstream from the U.S. 64 culvert near the confluence of the La Plata River with the San Juan River. The difference in the calculated sediment yield between the "typical" reach and cross section 3 indicates that between 81 and 97 percent of the bed-material sediment load could be deposited behind this culvert. However, these numbers are for comparison only as the model geometry from which they were calculated would change as deposition occurred during a flood. The total storage volume upstream of the U.S. 64 culvert was calculated to be about 190,000 cu yd. Comparing this volume with the bed-material yields in Tables 1 and 2 calculated using the Laursen-Copeland

function for average annual conditions, and considering that there is no evidence of large sediment deposits upstream from U.S. 64, one may deduce that the Laursen-Copeland function significantly over-predicts average annual bed-material sediment yield.

Table 1
Calculated Bed-Material Sediment Yield, La Plata River at Farmington

Function	Average-Annual		50 percent chance exceedance		1 percent chance exceedance	
	yd^3	acre-ft/square mile	yd^3	acre-ft/square mile	yd^3	acre-ft/square mile
Laursen-Copeland	196,000	0.208	61,000	0.065	1,202,000	1.278
Engelund-Hansen	45,000	0.048	12,000	0.013	424,000	0.451
Ackers-White	6,800	0.007	1,400	0.002	71,000	0.076

Table 2
Calculated Bed-Material Sediment Yield, La Plata River Upstream From U.S. 64 Culvert

Function	Average-Annual		50 percent chance exceedance		1 percent chance exceedance	
	yd^3	acre-ft/square mile	yd^3	acre-ft/square mile	yd^3	acre-ft/square mile
Laursen-Copeland	12,800	0.01	2,003	0.002	46,600	0.04
Engelund-Hansen	8,600	0.01	1,455	0.001	37,000	0.03
Ackers-White	1,300	0.001	201	0.0002	6,000	0.01

Due to the significant differences in sediment transport capacity along the La Plata River through Farmington and the high sediment yield potential, any project would require a detailed sedimentation study to evaluate both existing and project conditions. An adequate sediment analysis will require an HEC-6 numerical simulation that accounts for nonuniform water and sediment movement. This model would require better channel definition in the cross sections.

Total Sediment Yield

MacArthur and Wakeman (1983) did not discuss the erosion and sediment production on the La Plata. However, they stated that soils in the La Plata drainage basin are similar to those in the Animas drainage basin. The La Plata Basin falls in the same yield-class area on the Upper Colorado Region sediment yield maps in the MacArthur and Wakeman (1983) report, which would indicate total sediment yield rates of 0.42 to 1.0 acre-ft/square mile/year using the MacArthur and Wakeman approach.

4 San Juan River

Channel Stability

Navajo Dam was put into operation in 1962 and retains about 98 percent of the sediment entering the San Juan River from the upstream watershed (MacArthur and Wakeman 1983). MacArthur and Wakeman state that flooding on the San Juan River has been essentially controlled as a result of the construction of the dam (1983).

Limited field reconnaissance of the San Juan River included several bridge crossings from Blanco to Fruitland and the confluence of the Animas and the San Juan Rivers. The near-bank river bottom seemed to be mostly gravels and cobbles. There was evidence of bank erosion and the formation of middle bars that are typical of coarse-bed alluvial rivers. There appears to be an abundant supply of coarse gravels and cobbles in the river banks, and some banks have a large percentage of clay. Because of the depths and velocities in the San Juan River, no bed samples were taken.

Bed-material gradations for sediment transport calculations were obtained from limited USGS data at the Fruitland gage, 11 miles downstream from Farmington. Information on how these data were collected was not available, and the data must be used with caution. The gradation used is shown in Figure 31. These data indicate a bed gradation much finer than that of the Animas River and is much finer than observed along the edge of the water in the channel during the field reconnaissance. This apparent data discrepancy should be addressed in a more detailed sediment study.

The Albuquerque District provided HEC-2 files for the San Juan River from below Farmington to the Navajo Dam. SAM was used to calculate average hydraulic parameters from the HEC-2 model for the reach starting about 1.5 miles downstream from the confluence of the La Plata River upstream to just below the confluence of the Animas and the San Juan Rivers. Velocities and slopes for this section of the San Juan River are plotted for the 1 percent chance exceedance flood flow in Figures 32 and 33.

Bed-Material Sediment Yield

The reach-averaged hydraulic parameters from SAM were used to calculate sediment transport. The Ackers-White, Laursen-Copeland, and Engelund-Hansen sediment transport functions were used. The sediment transport rating curves developed for these functions are shown in Figure 34. The 1 percent chance exceedance flood hydrograph was not available, so sediment yield was calculated only for the average annual conditions. The flow-duration curve for the average annual sediment yield was developed from the San Juan near Farmington gage from mean daily flows between 1963 and 1991, Figure 35. This calculation is for bed-material load only and does not include the wash load that is contributed by the watershed.

Sediment yields, presented in the following tabulation, were calculated using the San Juan drainage area between Farmington and the Navajo Dam, which is 4,030 square miles.

Calculated Bed-Material Sediment Yield, San Juan River near Farmington

	Average Annual Yield	
Equation	yd^3	acre-ft/square mile
Laursen-Copeland	1,113,000	0.17
Engelund-Hansen	2,845,000	0.44
Ackers-White	888,000	0.14

For the San Juan River, the Engelund-Hansen equation predicts the highest sediment yield rather than the Laursen-Copeland function. This is attributed to the finer bed-material gradation used in the sediment transport calculations. This difference demonstrates the importance of conducting a sensitivity study using different transport functions. Relative predicted quantities will vary with differences in stream characteristics.

Total Sediment Yield

MacArthur and Wakeman (1983) state that the sediment yield rate for the San Juan River between Farmington and the Navajo Reservoir varies from 0.2 to 3.0 acre-ft/square mile/year. They base this estimate on sediment yield maps prepared by the Colorado Water Conservation Board and the United States Department of Agriculture.

5 Farmington Glade

Channel Stability

The drainage basin of Farmington Glade is situated between the basins of the Animas and the La Plata Rivers (Figure 1). A brief field investigation showed Farmington Glade to be well channelized with wide overbanks. At many places along the overbanks, there was evidence that the channel had been dredged. About 2 miles upstream of Glade Hills Drive, which is about 2.4 miles upstream from the confluence with the San Juan River, the channel was dry but well defined, about 40 ft wide and 3 ft deep. This reach has the potential to supply downstream reaches with a significant sediment load.

In order to obtain a better idea of the composition of the stream bed, three samples were taken. Just upstream of Glade Hills Drive, the stream was about 10 ft wide with a 1-ft-wide low-flow channel. Two bed material gradations were determined at this point, one from the low-flow channel and one from a bar in the main channel (Figure 36a). A third bed material gradation was determined from the supply reach about 2 miles upstream of Glade Hills Drive (Figure 36b). These bed material gradations are shown in Figure 37. Following Einstein's (1950) recommendation, the finest 10 percent of the gradation of this supply reach sample was excluded from the calculations for Farmington Glade, also shown in Figure 37.

Bed-Material Sediment Yield

Albuquerque District provided both HEC-RAS and HEC-1 files for Farmington Glade. To determine bed-material sediment yield from the upstream supply reach, a typical cross section was estimated based on field observations and limited topographic mapping. A 40-ft wide, 3-ft deep channel with an effective overbank width of 160 ft was used. Slope was determined from a USGS quad sheet. Roughness coefficients of 0.035 for the channel and 0.050 for the overbank were assigned. Hydraulic parameters were calculated using the SAM hydraulic design package.

Sediment yield was calculated using SAM. Sediment transport rating curves were calculated for the three sediment transport functions used on the

Animas River: Ackers-White, Laursen-Copeland and Engelund-Hansen. The sediment transport rating curves developed for these functions are shown in Figure 38. The 50 percent and 1 percent chance exceedance flood hydrographs used for the sediment yield calculations were taken from the District-supplied HEC-1 output files. The hydrographs at 30th Street were used for this supply reach. A flow-duration curve was unavailable to determine average annual yield. Results are shown in the following tabulation. Acre-feet per square mile was calculated using the Farmington Glade drainage area, 36.6 square miles.

Calculated Bed-Material Sediment Yield, Farmington Glade Supply Reach

Function	50 percent chance exceedance		1 percent chance exceedance	
	yd^3	acre-ft/square mile	yd^3	acre-ft/square mile
Laursen-Copeland	8,770	0.15	105,000	1.78
Engelund-Hansen	11,400	0.19	212,000	3.59
Ackers-White	2,760	0.05	33,700	0.57

To determine the effects on sediment yield of ponding behind culverts, hydraulic parameters from the HEC-RAS model from two cross sections upstream from Apache Street were averaged. The Murray Street hydrograph from the HEC-1 file was used. Murray Street is less than one-quarter mile upstream from the mouth of Farmington Glade, and Apache Street is about one mile upstream of the mouth. Comparing sediment yield through this ponding reach to that of the supply reach, it was determined that for the 1 percent chance exceedance flood less than 1 percent of sediment from the supply reach will pass through the system. The high-sand load will most likely deposit upstream of culverts. For the 50 percent chance exceedance flood, about 6 percent will pass through the system.

Due to the significant differences in sediment transport capacity along Farmington Glade and the high sediment yield potential, any project would require a detailed sedimentation study to evaluate both existing and project conditions. This would include an HEC-6 numerical simulation that accounts for nonuniform water and sediment movement. Better channel definition in the cross sections would be required.

Total Sediment Yield

MacArthur and Wakeman (1983) did not discuss the erosion and sediment production on Farmington Glade. However, they stated that the soils in this basin are similar to the soils in the Animas basin, susceptible to accelerated erosion even under normal rainfall conditions. The Farmington Glade Basin falls in the same yield-class area on the Upper Colorado Region sediment yield maps in the MacArthur and Wakeman (1983) report, 0.42 - 1.0 acre-ft/square mile/year. These estimates are for total sediment yield.

6 Data Requirements for Detailed Sediment Study

Channel geometry is inadequately defined in existing HEC-2 and HEC-RAS data files of the four rivers studied. More detailed cross-section data are required for these streams. This may require field surveys.

Better definition of bed characteristics, including subsurface gradations, armor layer gradation, and bedrock or hard point location, is needed for all four streams. It is important that the full range of bed-material be included in this inventory, including the largest boulders. This will require a field data collection program on the order of a week for each stream studied. This program should be conducted at low water. Data collection on the San Juan River would take longer, depending on the length of the study reach.

Suspended sediment data collection on the Animas and San Juan River should continue in order to determine if trends in watershed erosion rates occur. Samples collected at high flows should have laboratory particle size analyses performed. These data are essential for size class analysis. If projects are planned for the La Plata River or Farmington Glade, an intensive suspended sediment data collection program should commence immediately. These streams are significantly different from the Animas and San Juan Rivers; therefore, sediment transport characteristics are expected to be different. Calculated sediment yield has a much higher uncertainty associated with it than measured yield. Particle size analysis should be conducted on all samples.

A baseline survey of the channels should be conducted. This would include cross-section and profile surveys that could be resurveyed after a flood or after several years to determine if any aggradation or degradation trends exist. These data could be used to verify a numerical model of the reach. An aerial survey should be conducted to establish existing planform. Surveys at a later date could then be used to assess planform stability and bank erosion quantities.

7 Conclusions

The existing channels of the San Juan and Animas Rivers appear to be relatively stable in terms of aggradation and degradation. Bank erosion is occurring, but does not appear to be excessive. However, widespread bank erosion and severe localized erosion at structures can be expected during major floods. Flood control projects that have insignificant effects on existing hydraulic parameters, i.e., set-back levees, would not require detailed sediment studies. However, a project that changes existing conditions, such as channel enlargement, diversions, or dams, could have a significant impact on channel stability, and a detailed sediment study would be required.

The sediment impact assessment determined that the existing channels on the La Plata River and Farmington Glade will have sediment deposition problems upstream from culverts during large floods, and then degradation and erosion problems downstream from culverts. Any flood control project on these streams would require a more detailed sediment study.

MacArthur and Wakeman (1983) suggested that data acquisition and field monitoring programs be developed in order to quantify essential sediment transport characteristics of the Animas River under various flow conditions. Further analytical work should include examination of river regime, bed and bank stability, and the possibility of project-induced aggradation or degradation.

Additional data are required for more detailed sediment studies. The data acquisition program should include the continuing collection of stream flow data and suspended sediment data at the Farmington gages on the Animas and San Juan Rivers. Laboratory analyses should include particle size distribution especially for samples taken at high flows. Suspended sediment data on the La Plata River and on Farmington Glade should be collected, as these streams are significantly different from the Animas and San Juan Rivers. Aerial photos should be taken at regular intervals, i.e., every 10 years, and after large flood events to help quantify lateral river migration and bank caving tendencies. A bed-material collection program should be instituted, collecting at low water to determine longitudinal and lateral variations. Bedrock outcrops should be identified. Both surface and subsurface gradations should be collected. Better cross-section definition is required on all four rivers studied.

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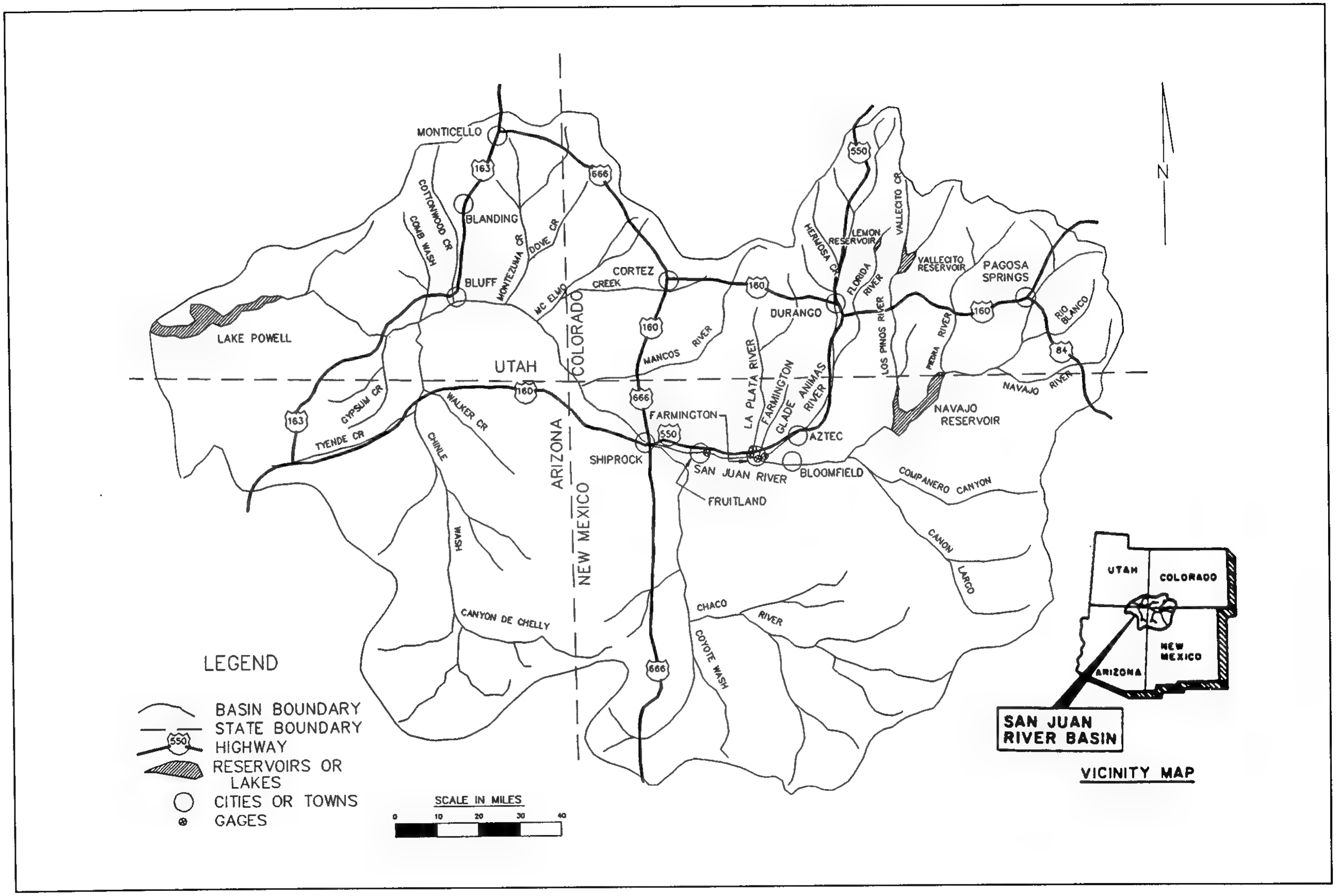


Figure 1. Location of San Juan River and associated basins

a. Downstream of Browning Bridge, Wolman count taken to the end of the far bar

b. Upstream of Broadway Bridge, looking across the chute towards the middle bar

Figure 2. Bed-material sample sites, Animas River

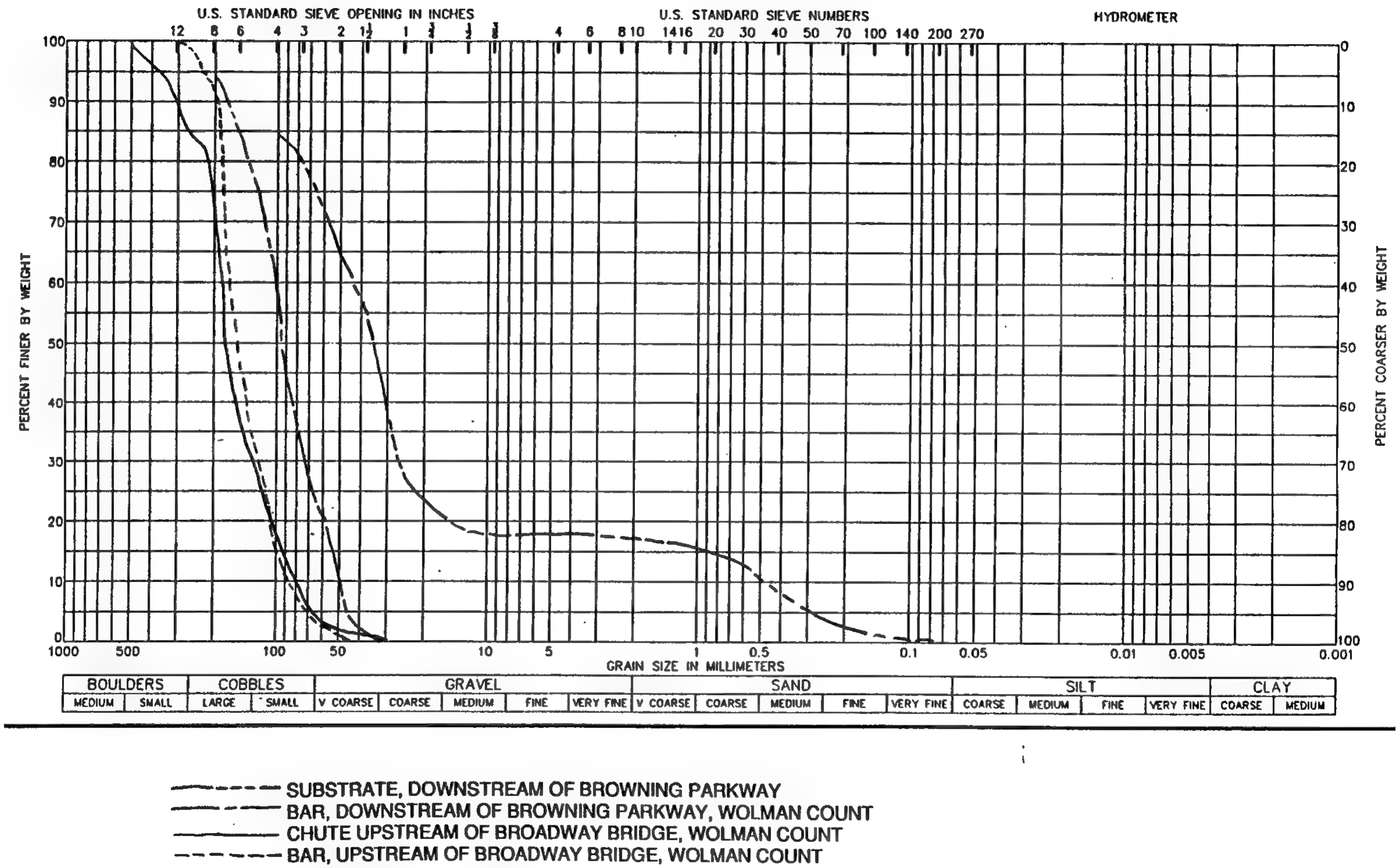


Figure 3: Bed gradations, downstream of Browning Parkway and upstream of Broadway Bridge

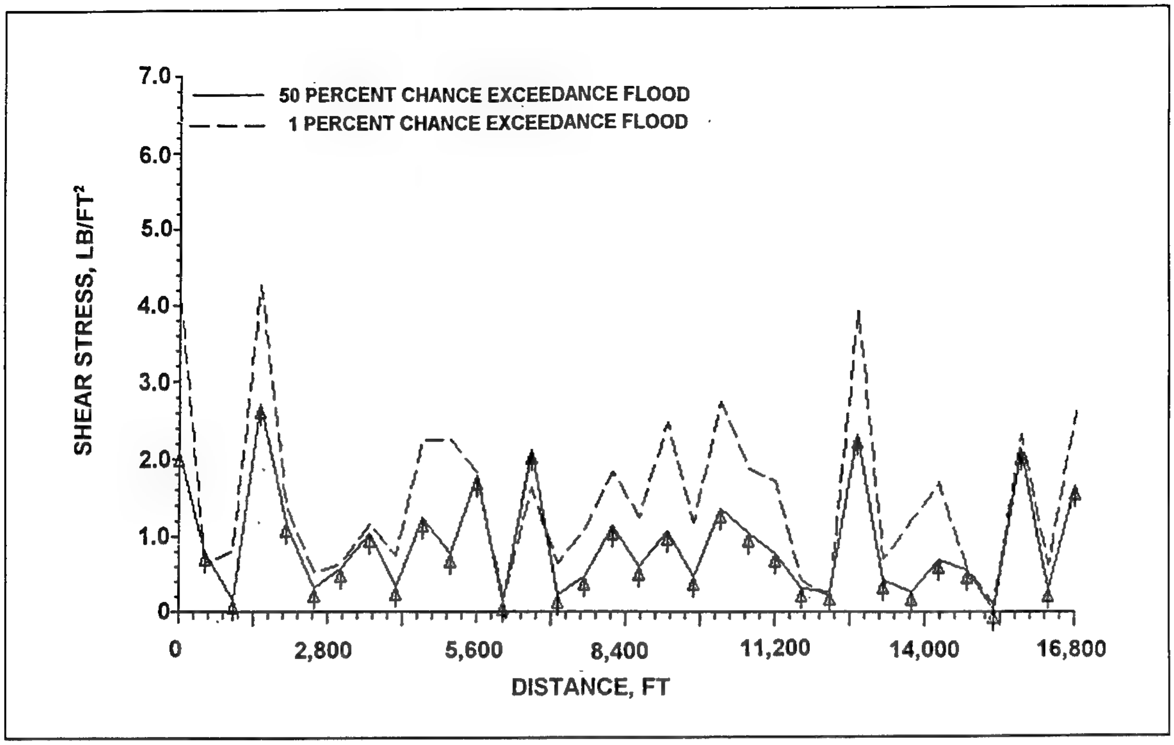


Figure 4. Average shear stress from HEC-2 model, Animas River at Farmington

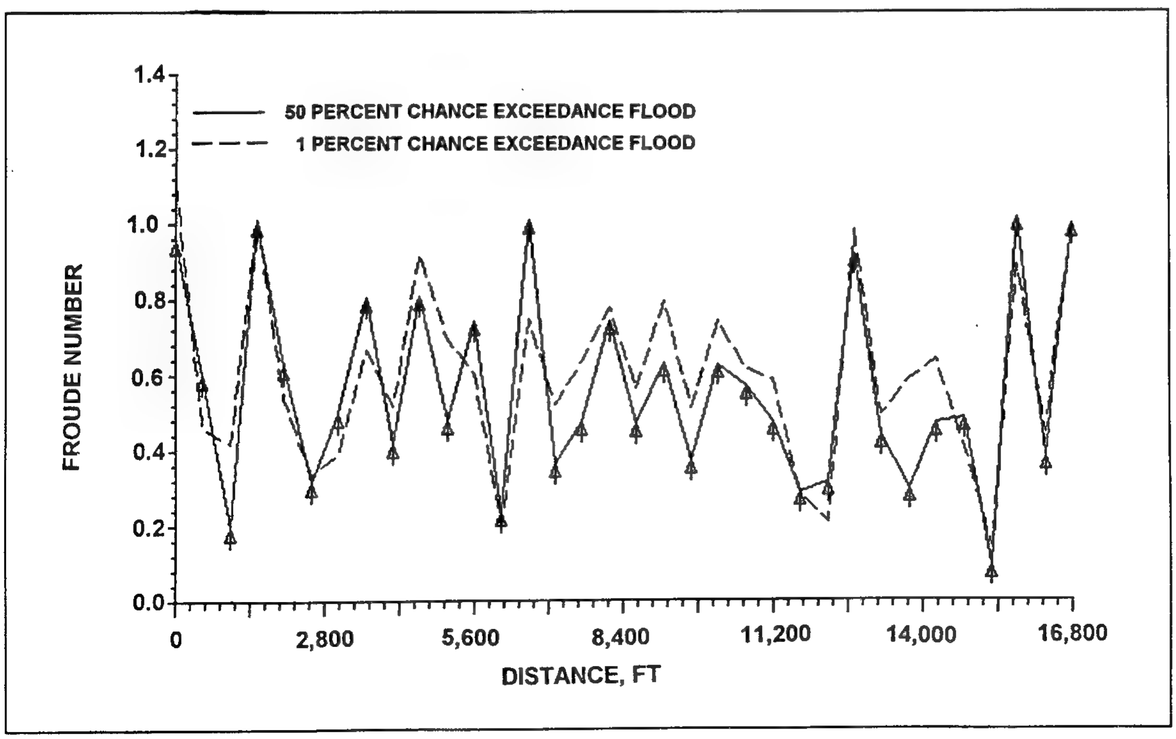


Figure 5. Froude number from HEC-2 model, Animas River at Farmington

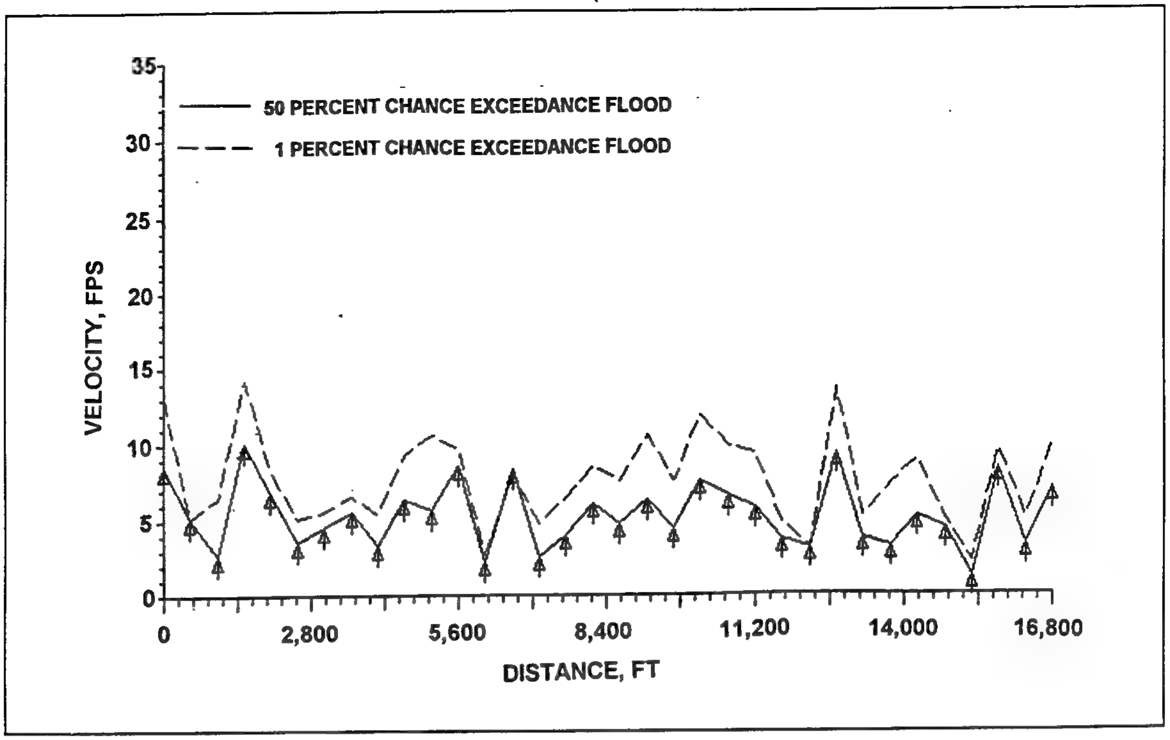


Figure 6. Channel velocity from HEC-2 model, Animas River at Farmington

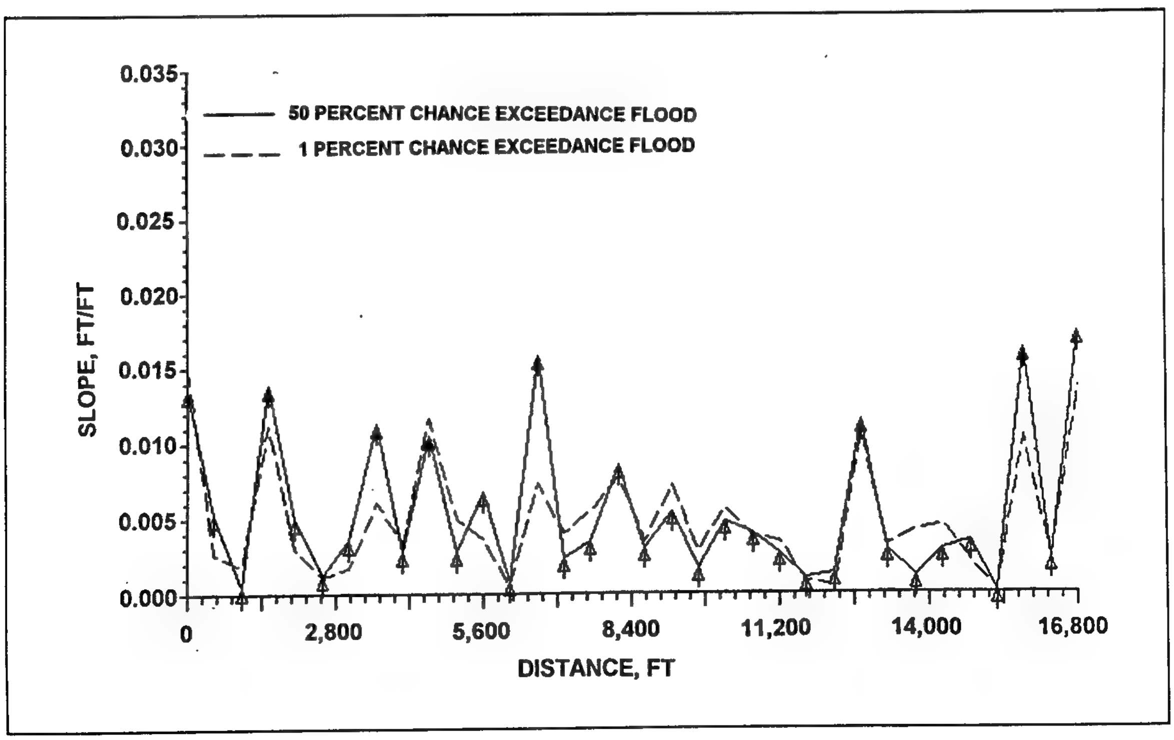


Figure 7. Slope from HEC-2 model, Animas River at Farmington

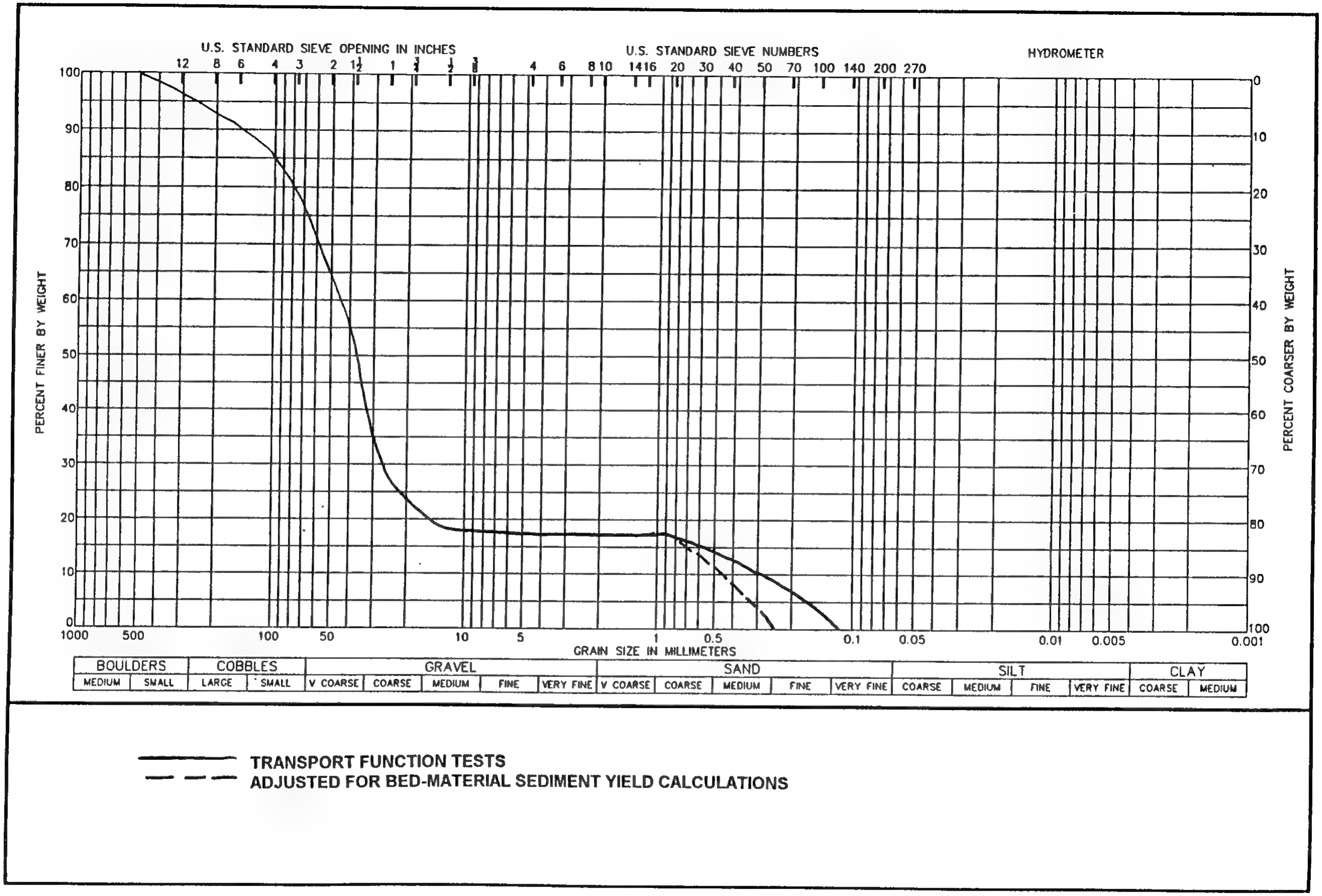


Figure 8. Normalized bed gradations used for sediment transport function testing and for sediment yield calculations

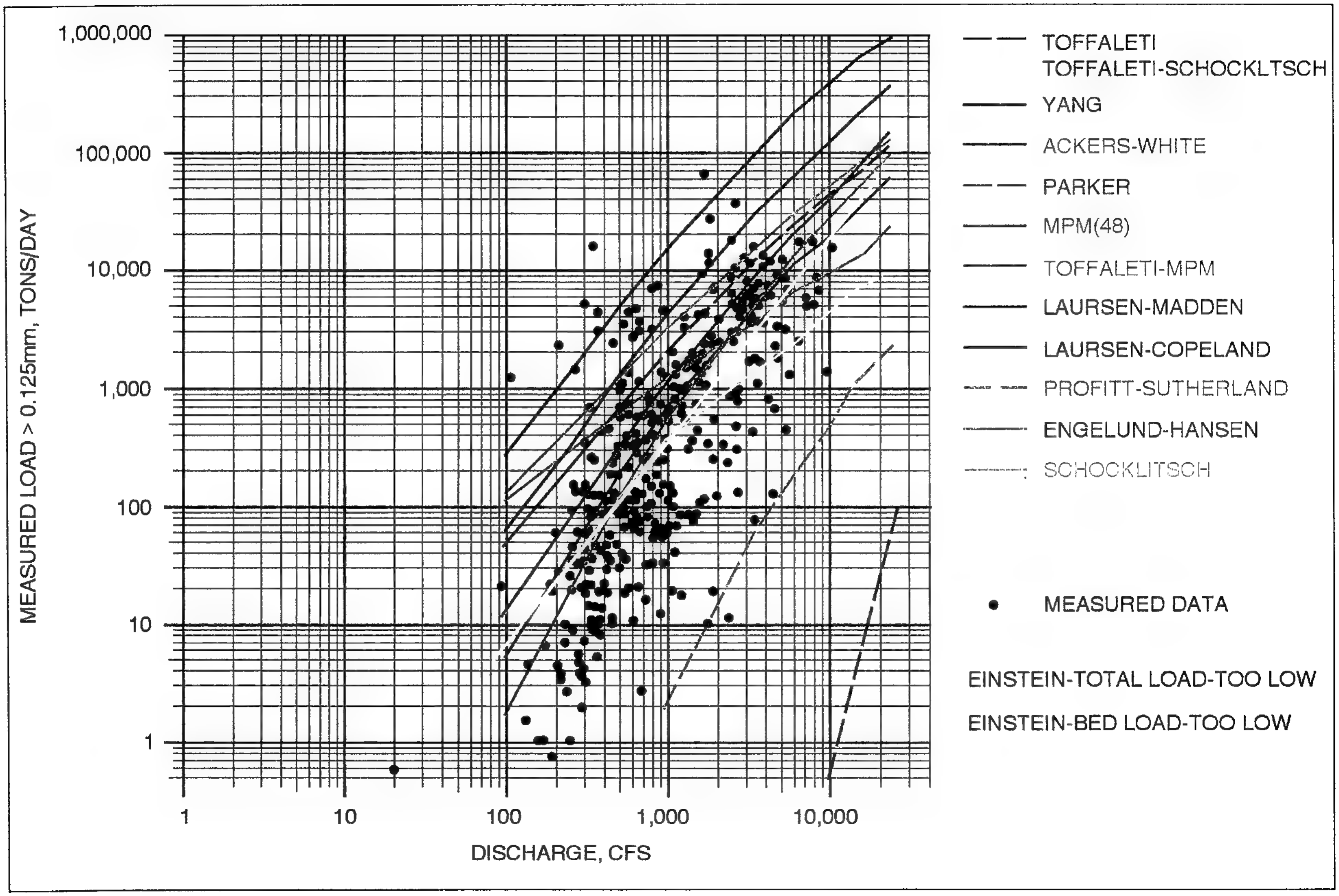


Figure 9. All sediment transport function results versus measured data, sizes greater than 0.125 mm

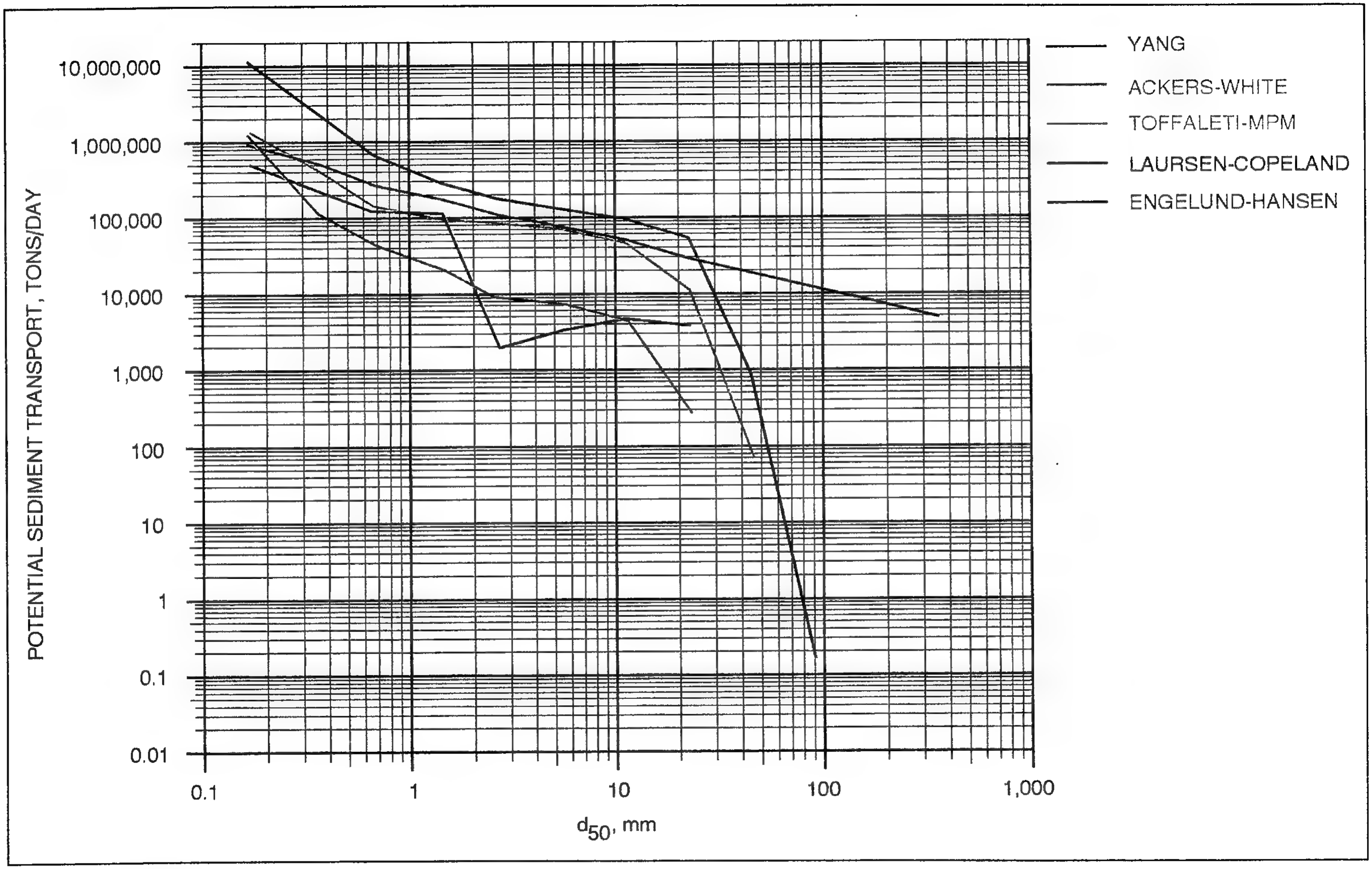


Figure 10. Potential sediment transport

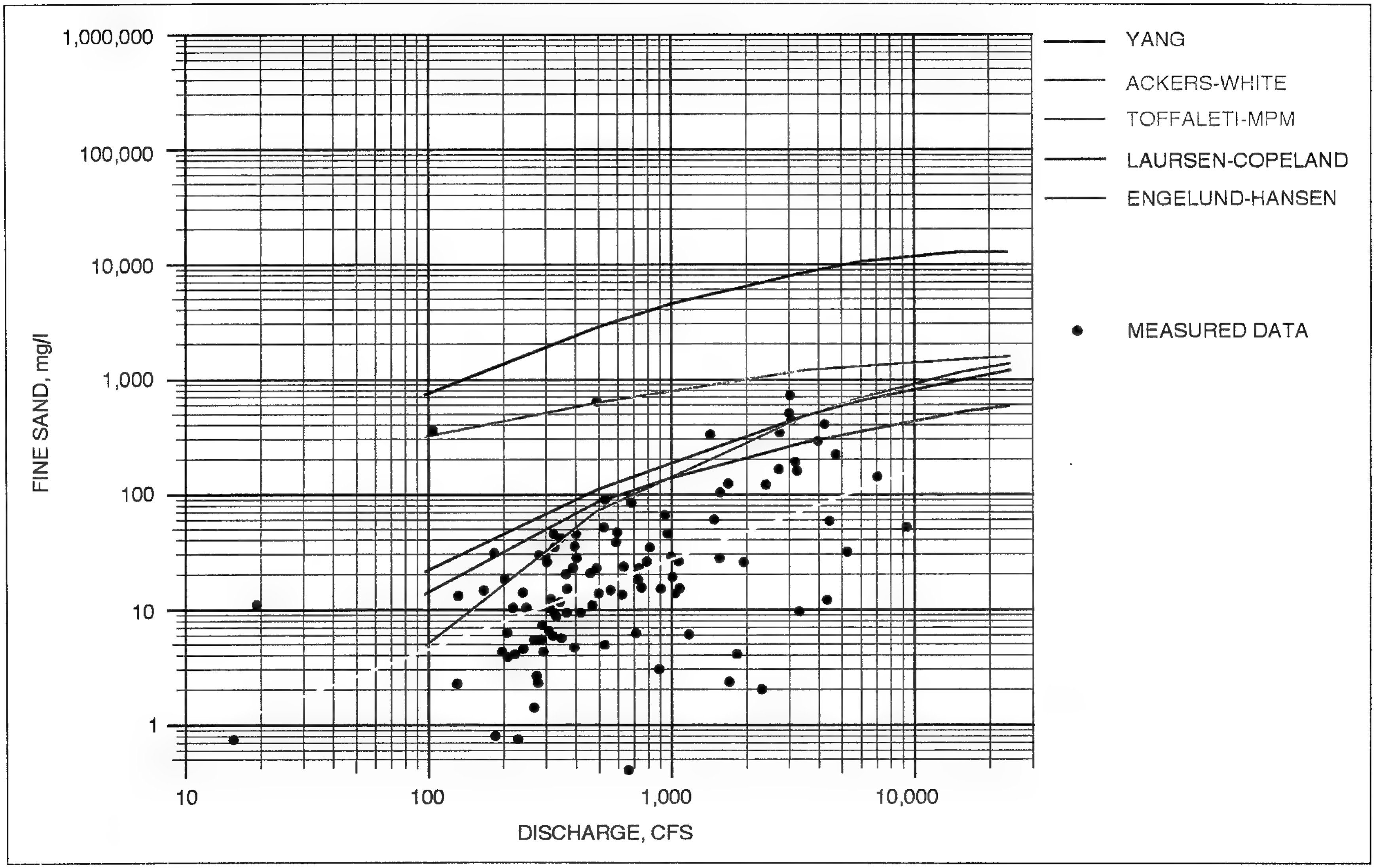


Figure 11. Measured load versus calculated load, Animas River, fine sand

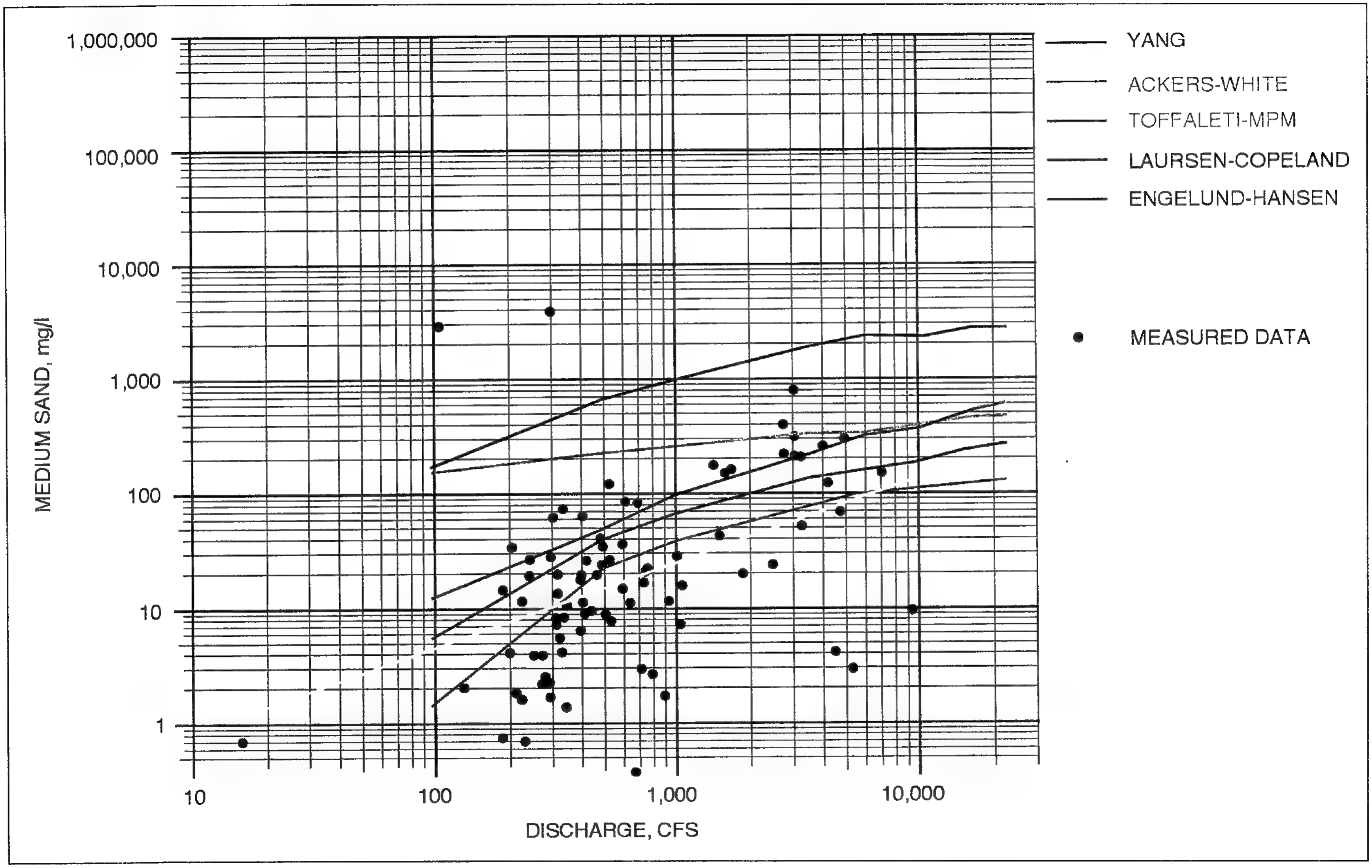


Figure 12. Measured load versus calculated load, Animas River, medium sand

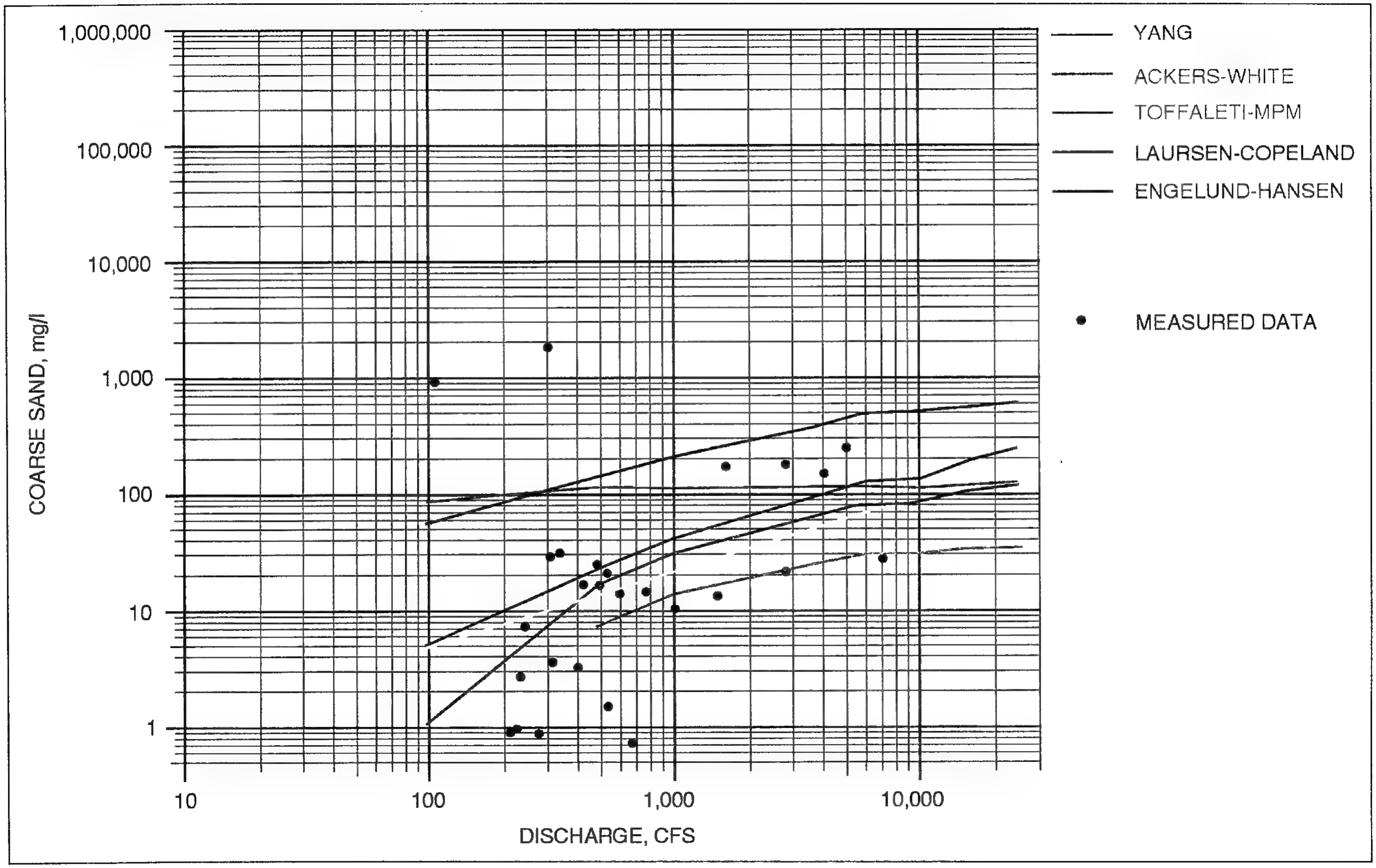


Figure 13. Measured load versus calculated load, Animas River, coarse sand

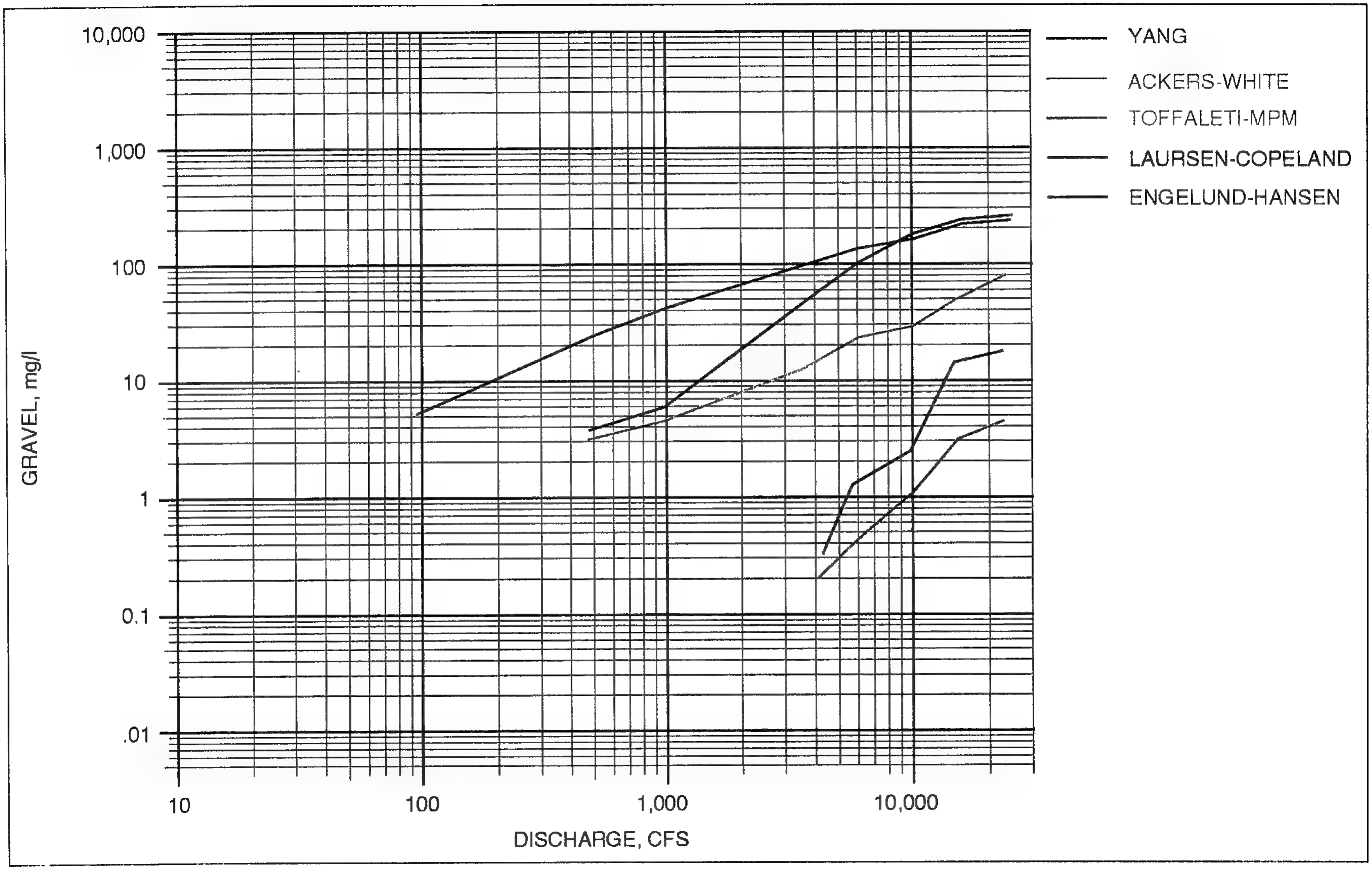


Figure 14. Calculated load, Animas River, gravel. No measured data were available

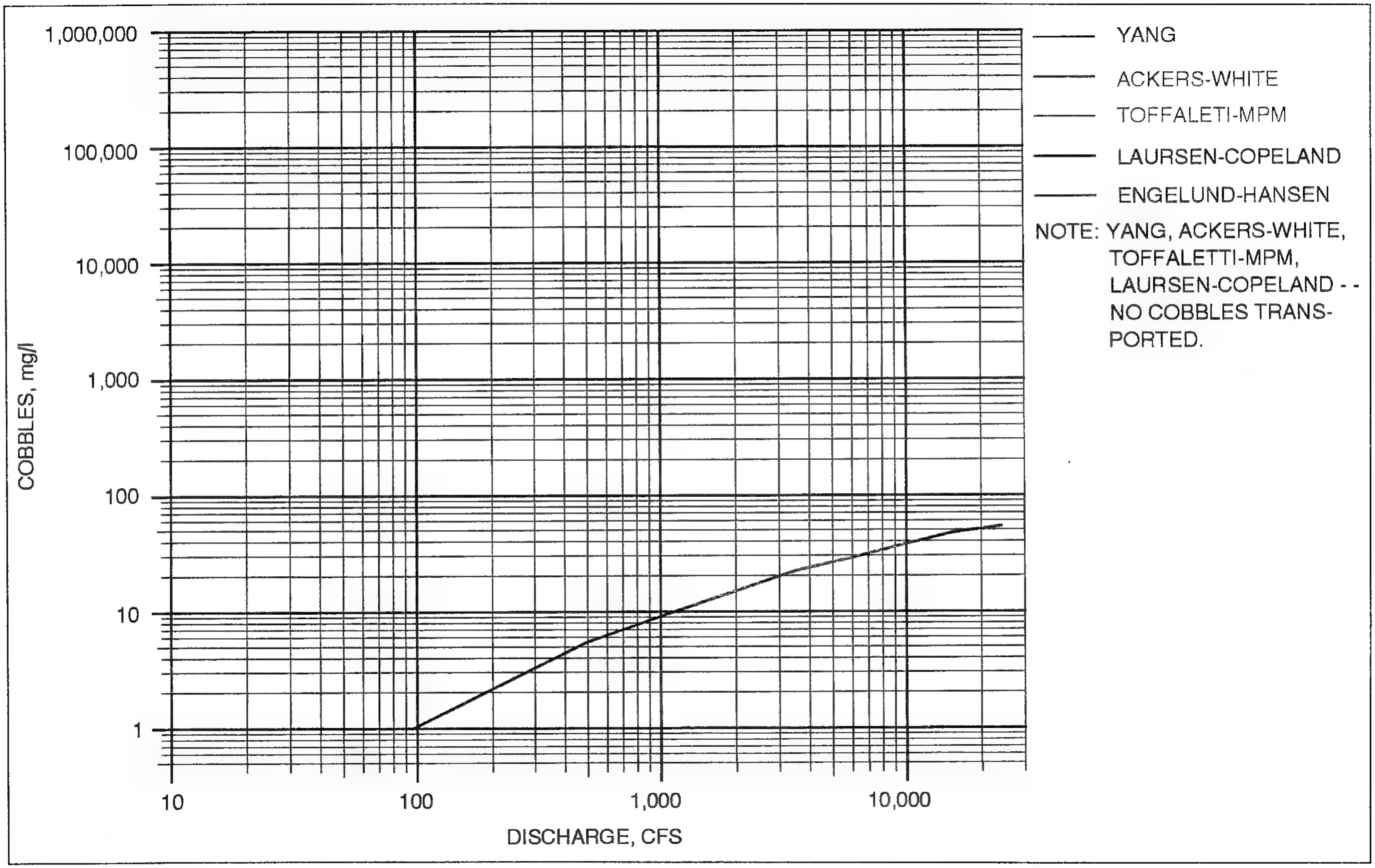


Figure 15. Calculated load, Animas River, cobbles. No measured data were available

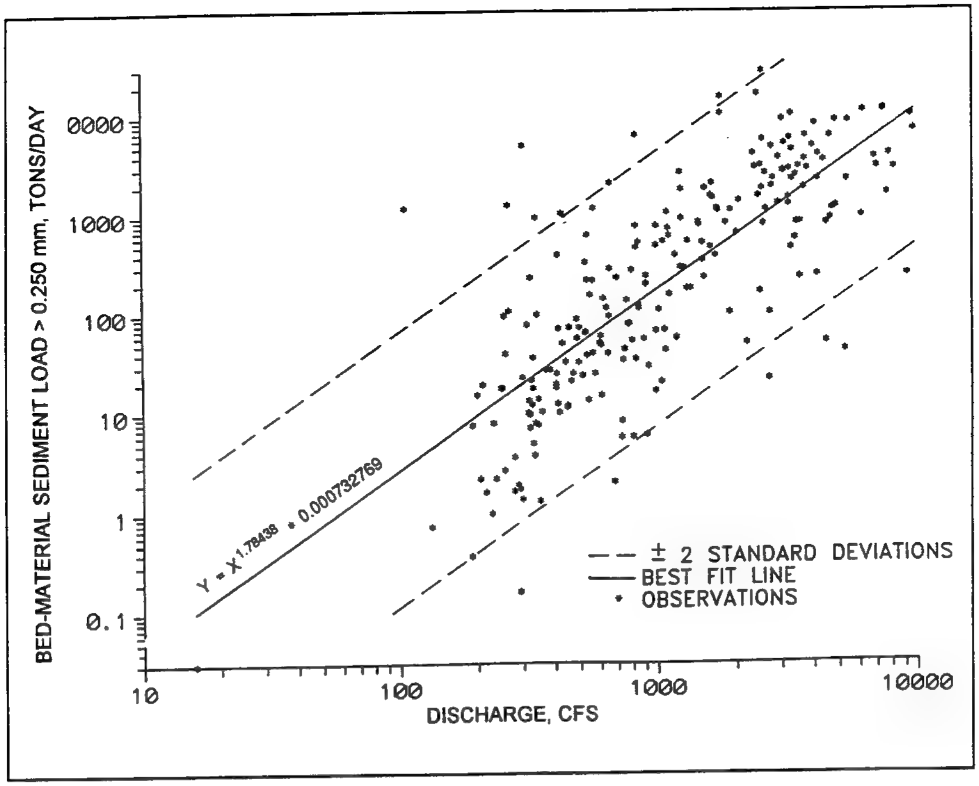


Figure 16. Regression curve of measured data, sizes greater than 0.25 mm, Animas River

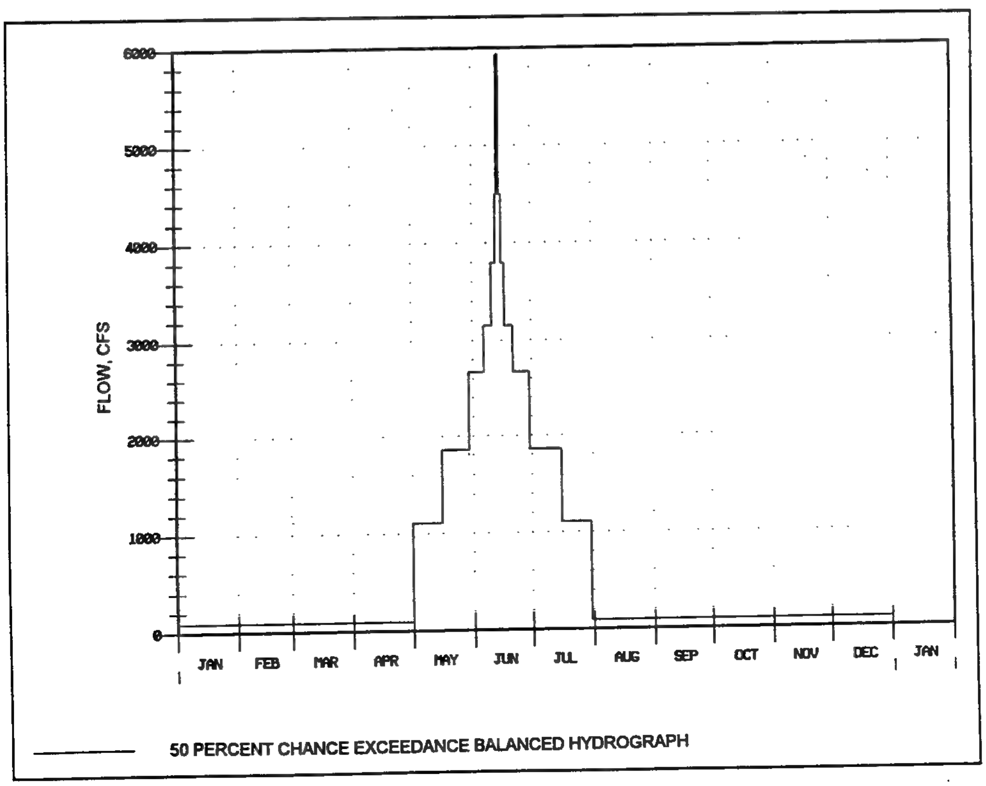


Figure 17. 50 percent chance exceedance balanced hydrograph, Animas River

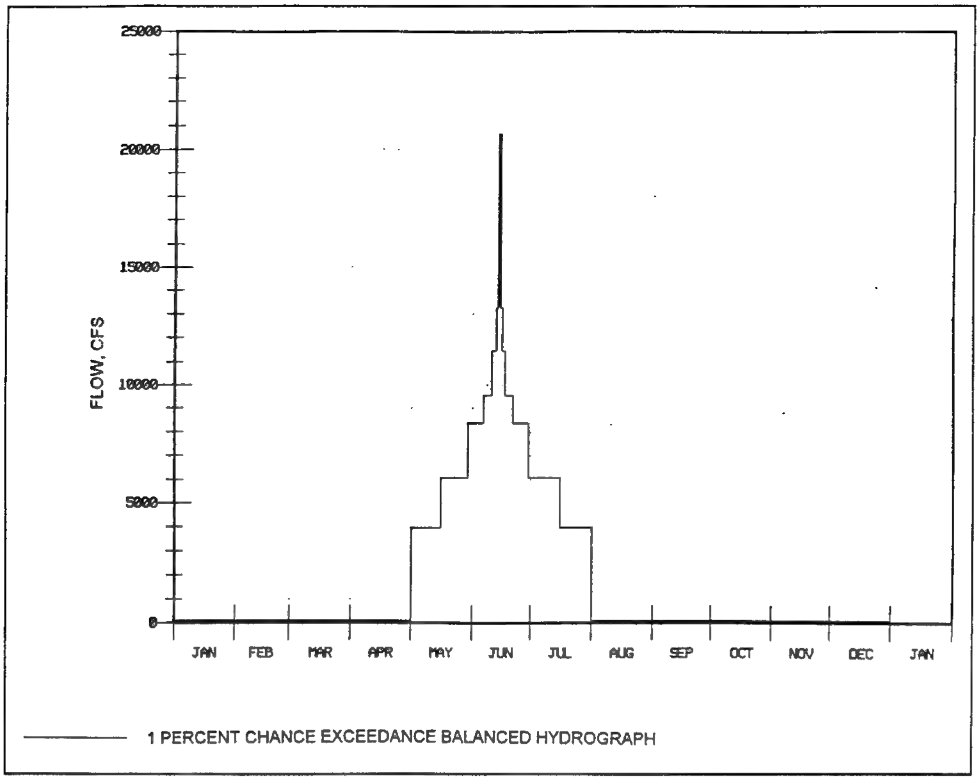


Figure 18. 1 percent chance exceedance balanced hydrograph, Animas River

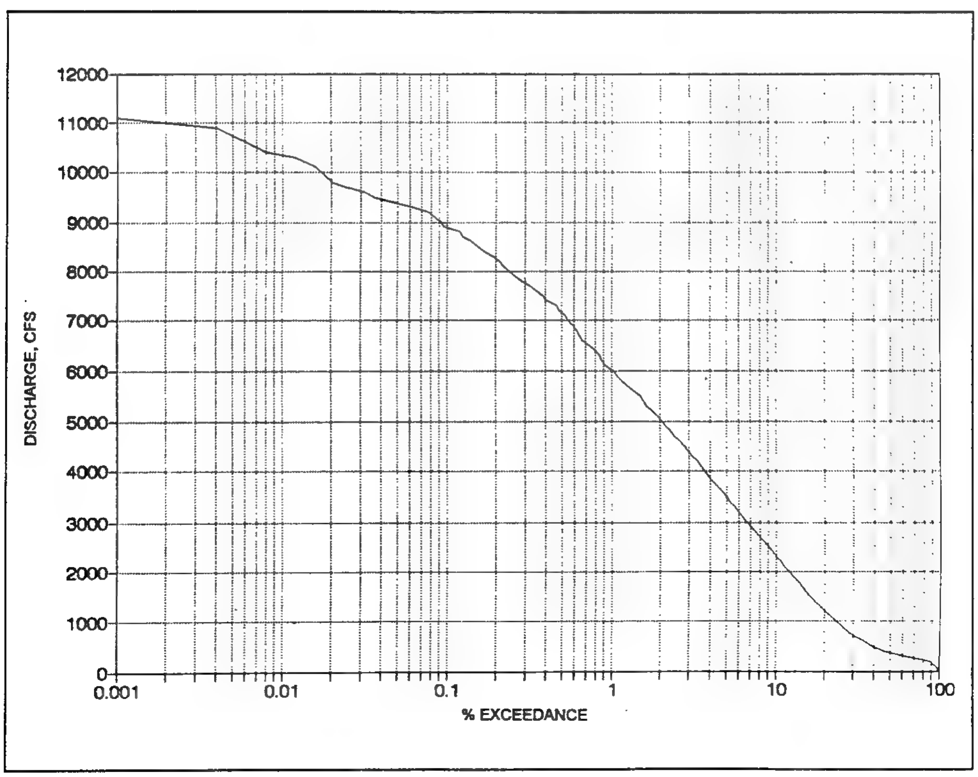


Figure 19. Flow-duration curve, Animas River

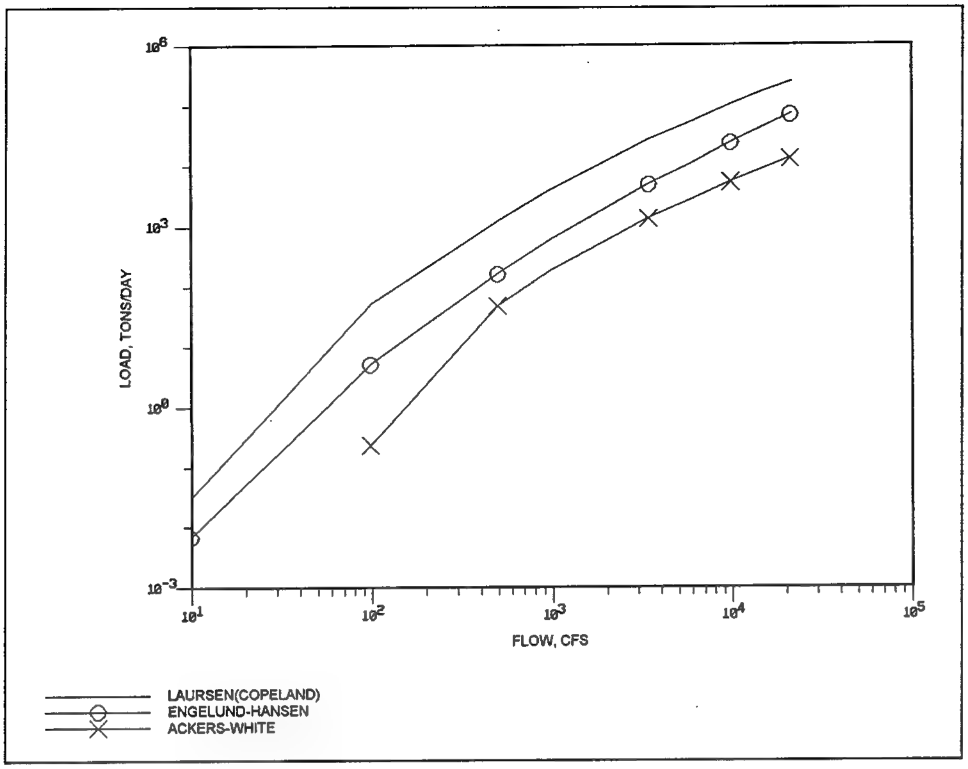


Figure 20. Sediment transport rating curves for material greater than 0.25 mm, Animas River

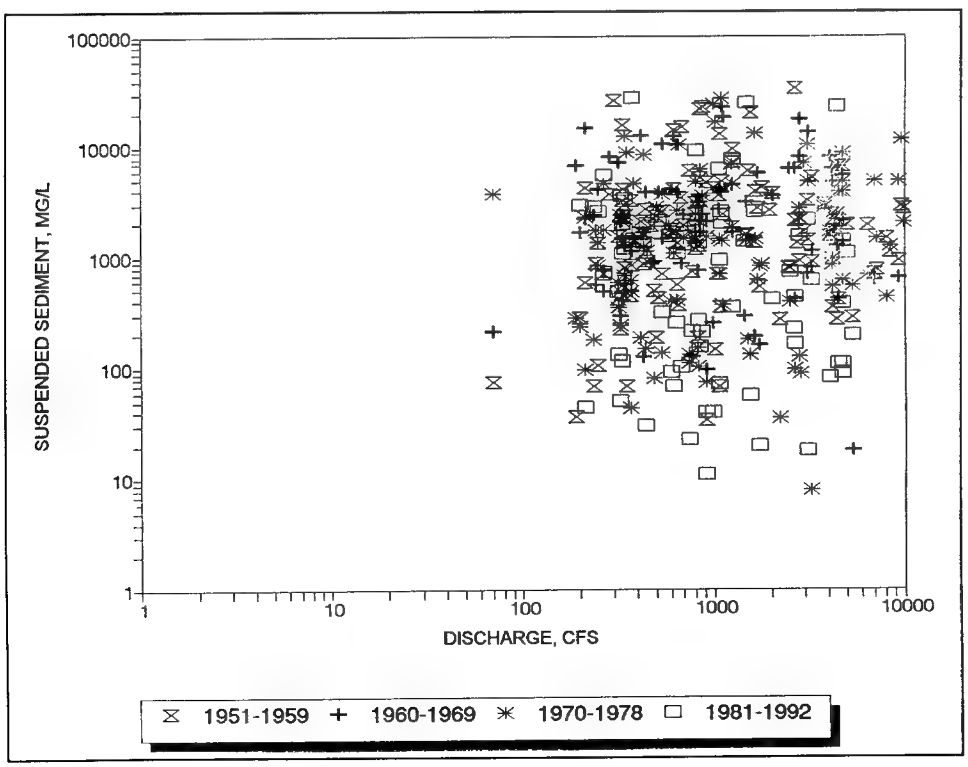
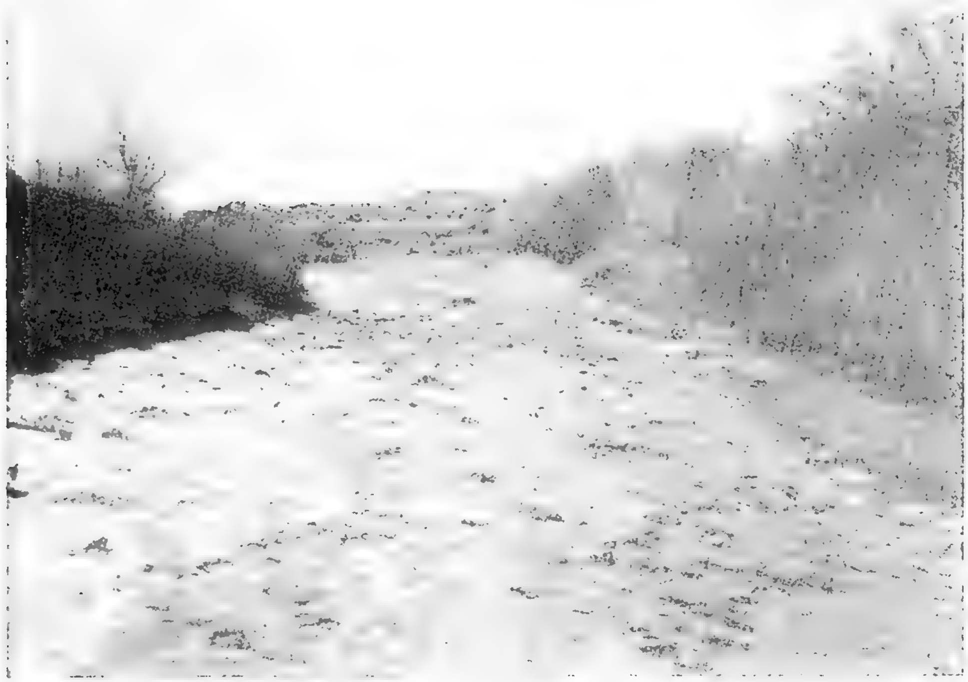


Figure 21. Comparison of Animas River prototype data by decade, 1951-1993

a. From the vegetated overbanks upstream of Glade Hills Drive



b. From a bar upstream of Glade Hills Drive

Figure 22. Bed-material sample sites, La Plata River (Continued)

c. From a bar upstream of the gage

Figure 22. (Concluded)

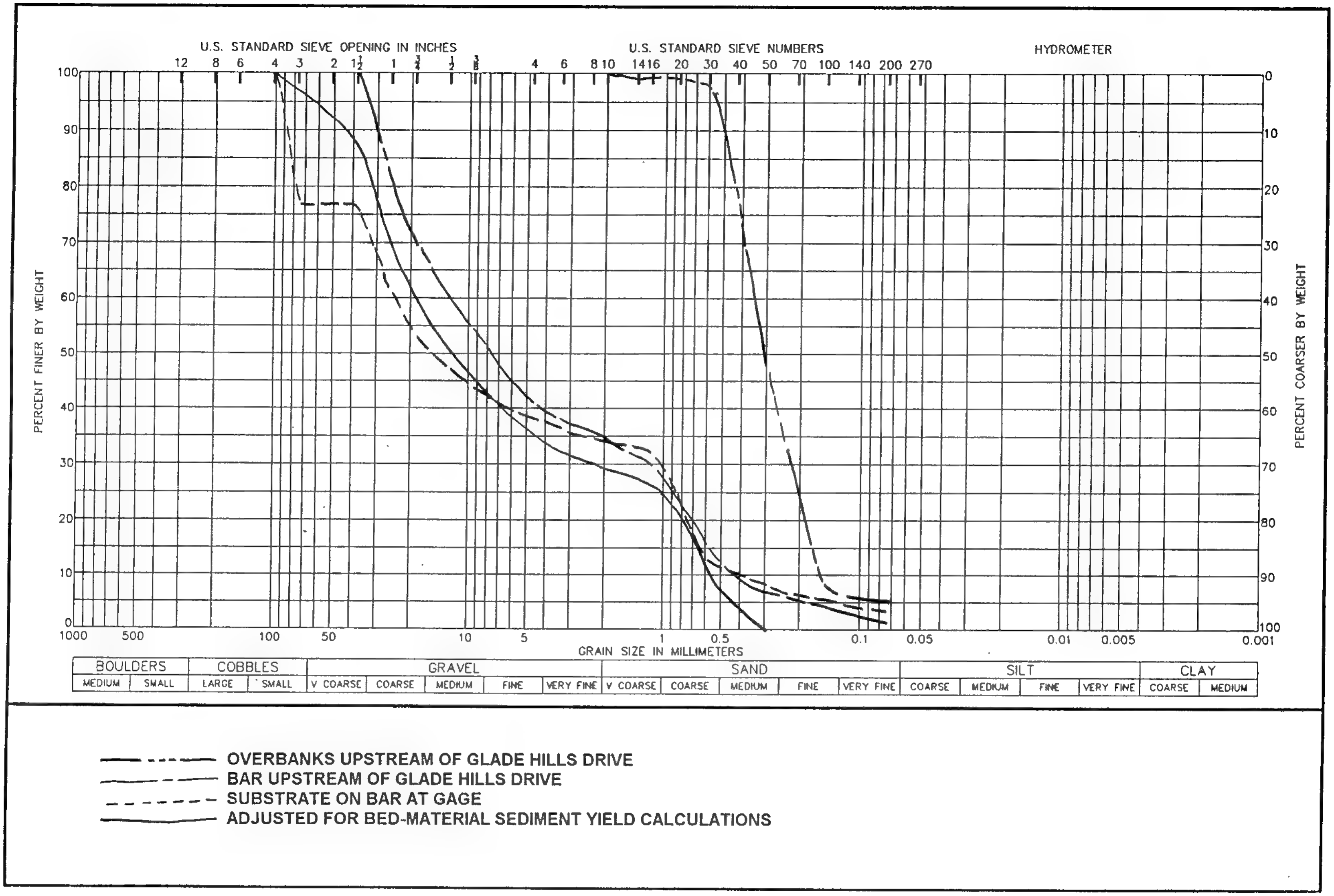


Figure 23. Bed-material gradations, La Plata River

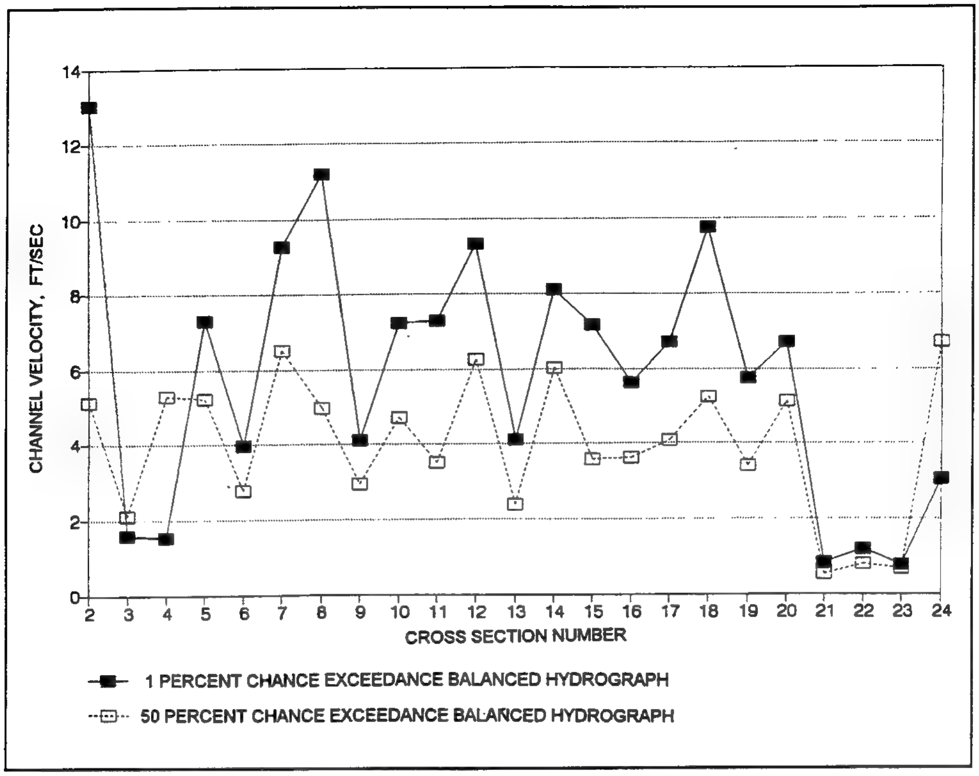


Figure 24. Channel velocity from HEC-RAS model, La Plata River

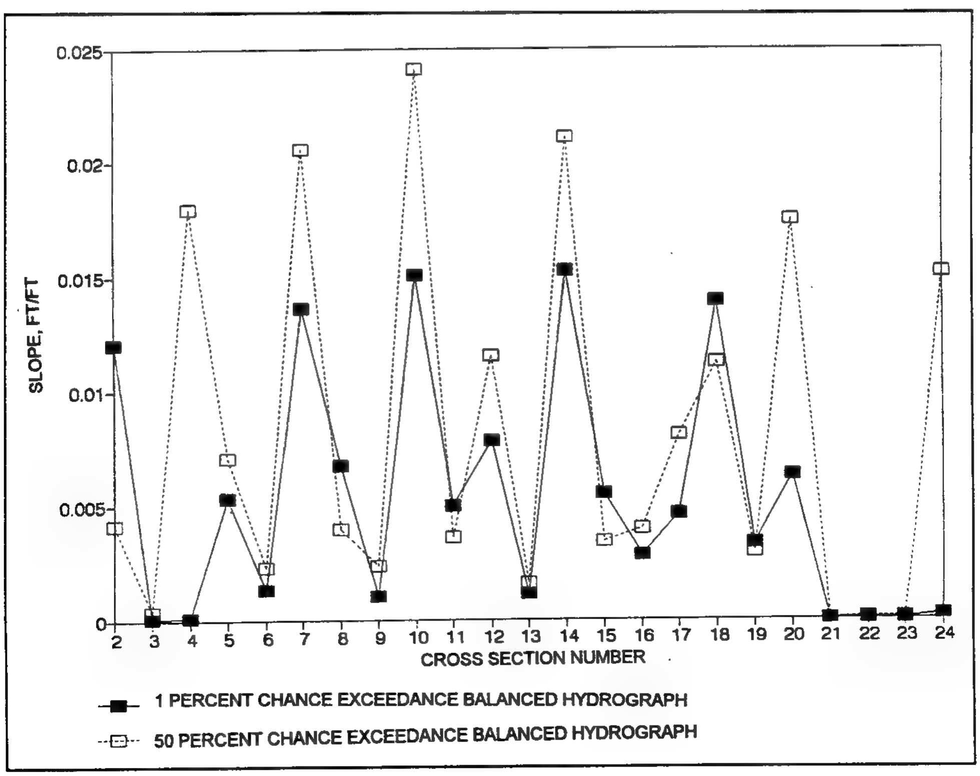


Figure 25. Slope from HEC-RAS model, La Plata River

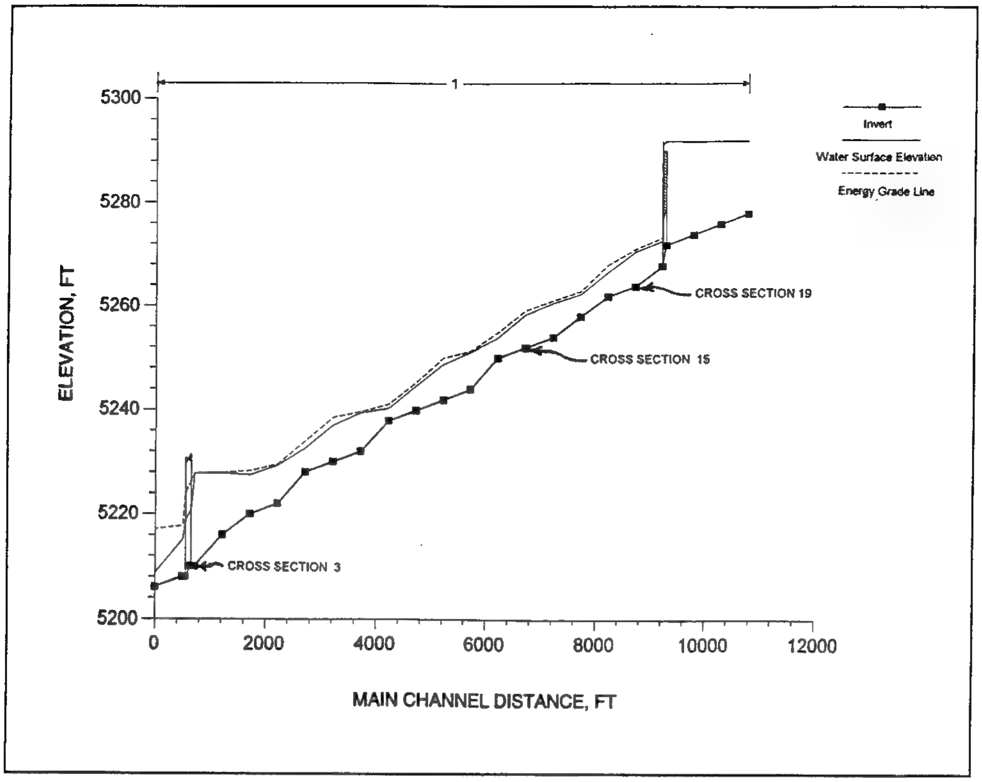


Figure 26. Profiles, La Plata River

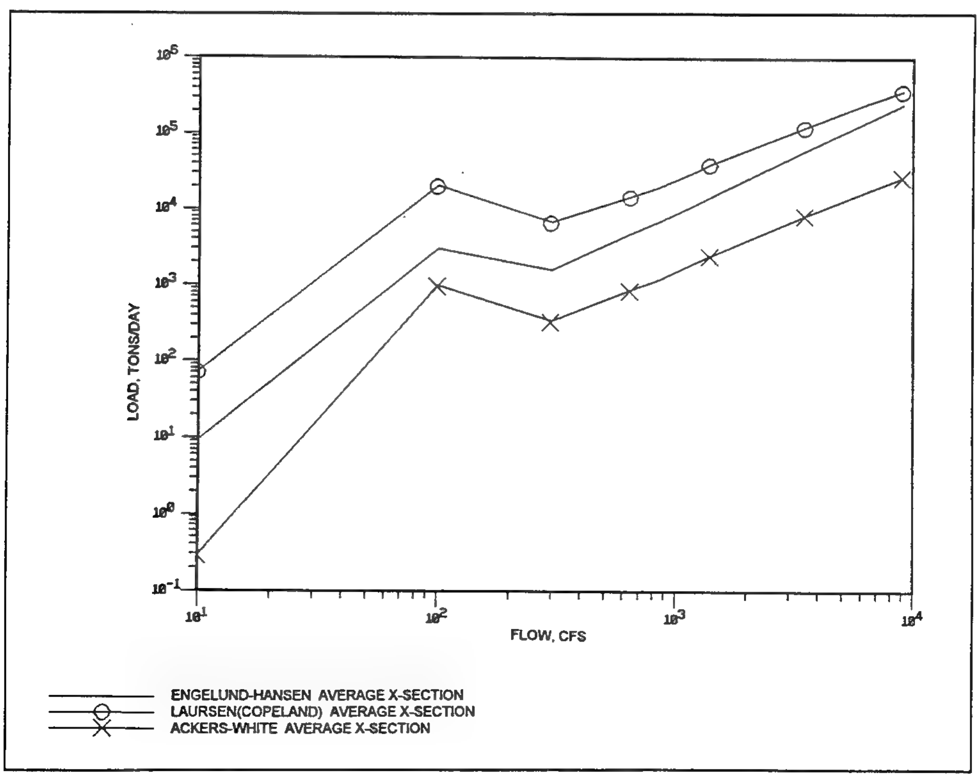


Figure 27. Sediment transport rating curves for material greater than 0.25 mm, La Plata River

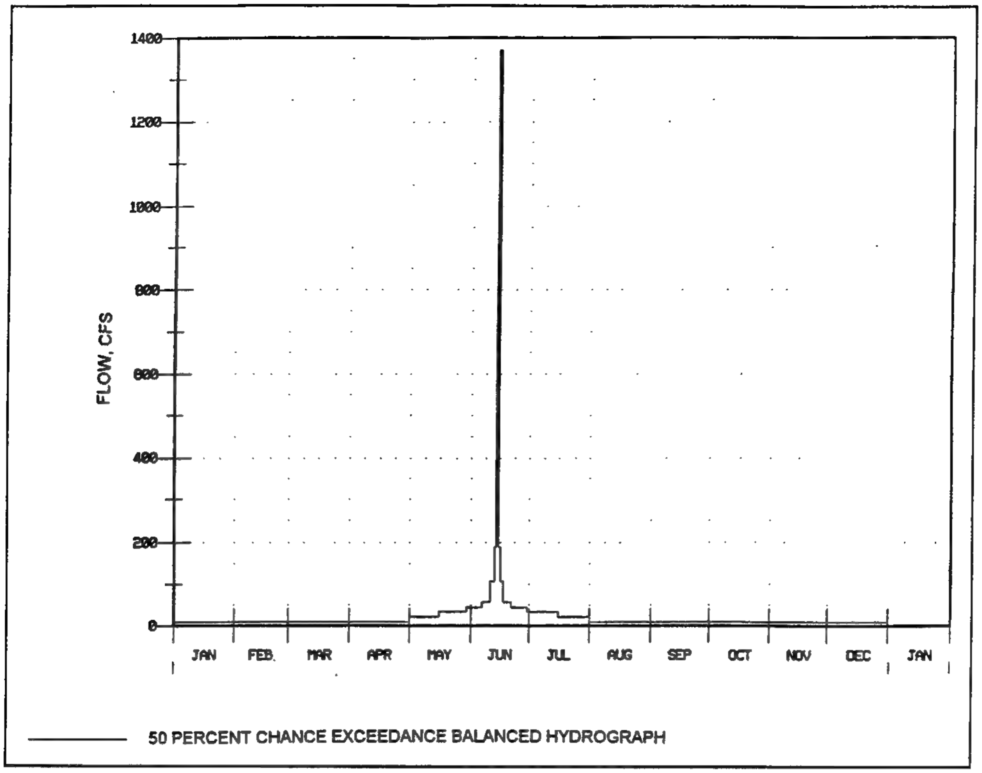


Figure 28. 50 percent chance exceedance hydrograph, La Plata River

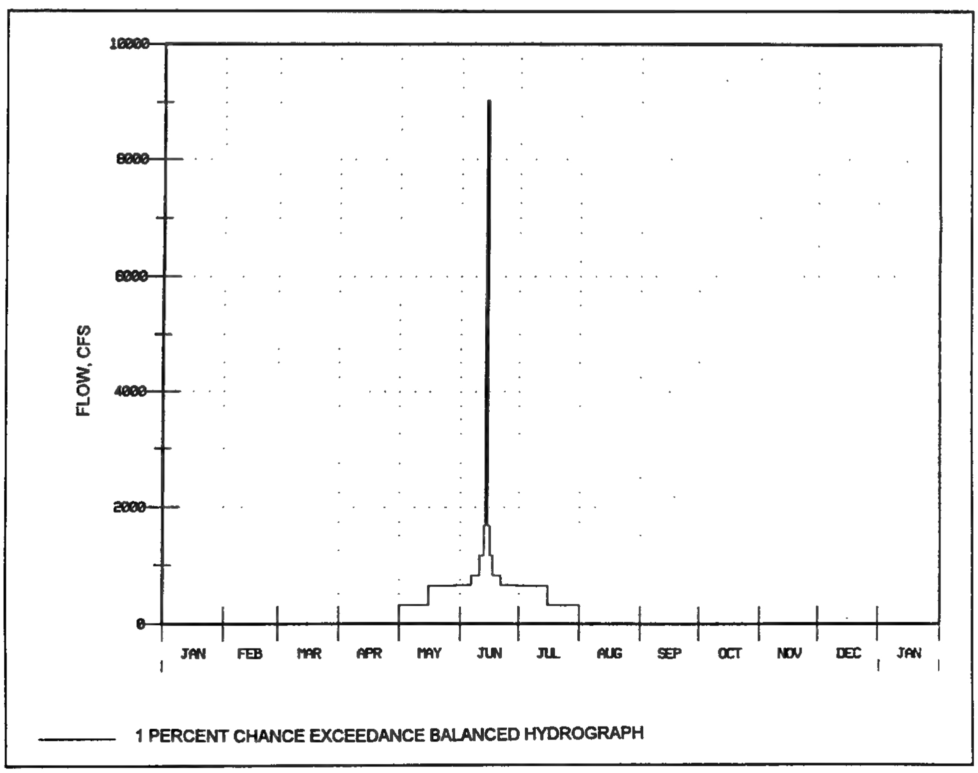


Figure 29. 1 percent chance exceedance hydrograph, La Plata River

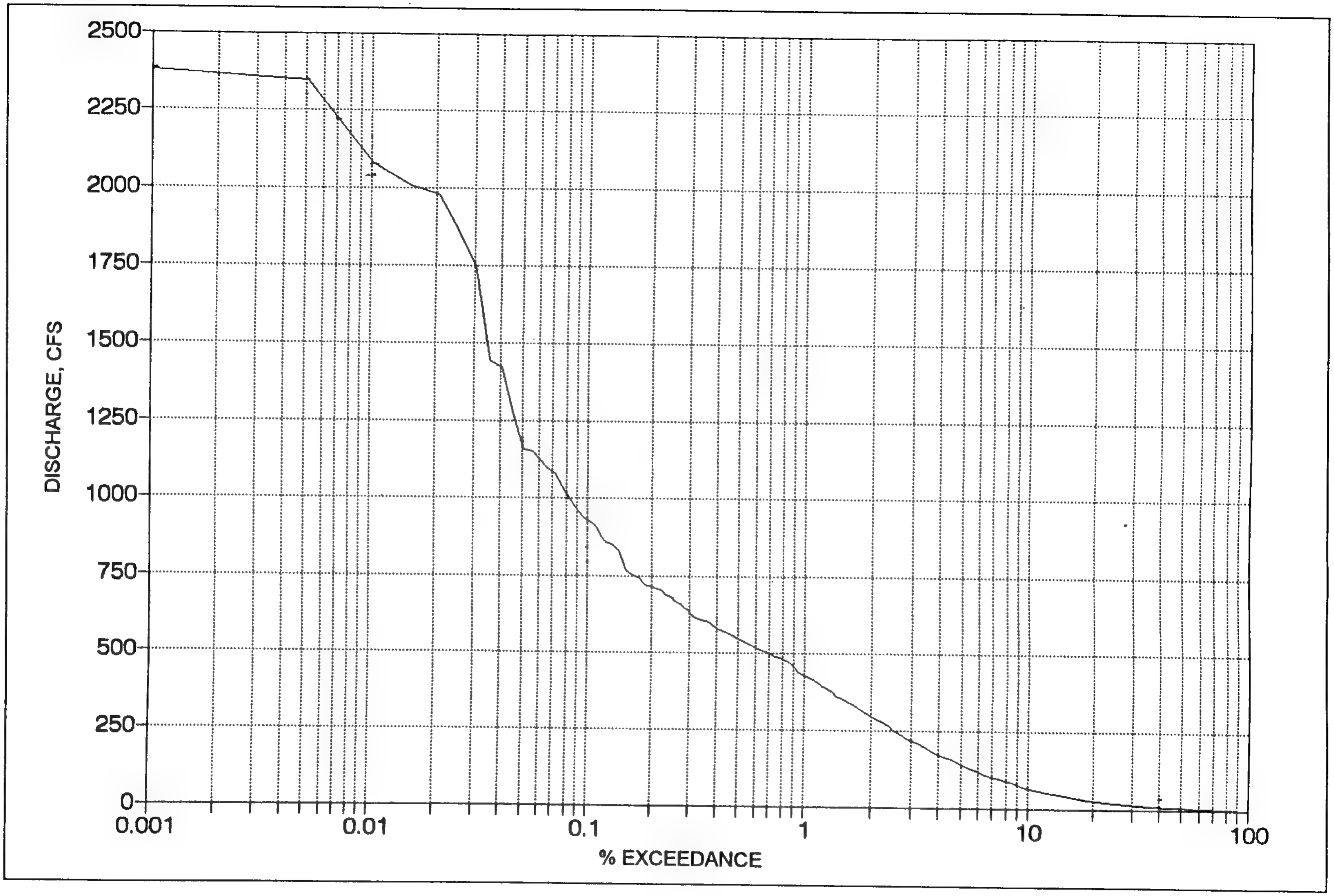


Figure 30. Flow-duration curve, La Plata River

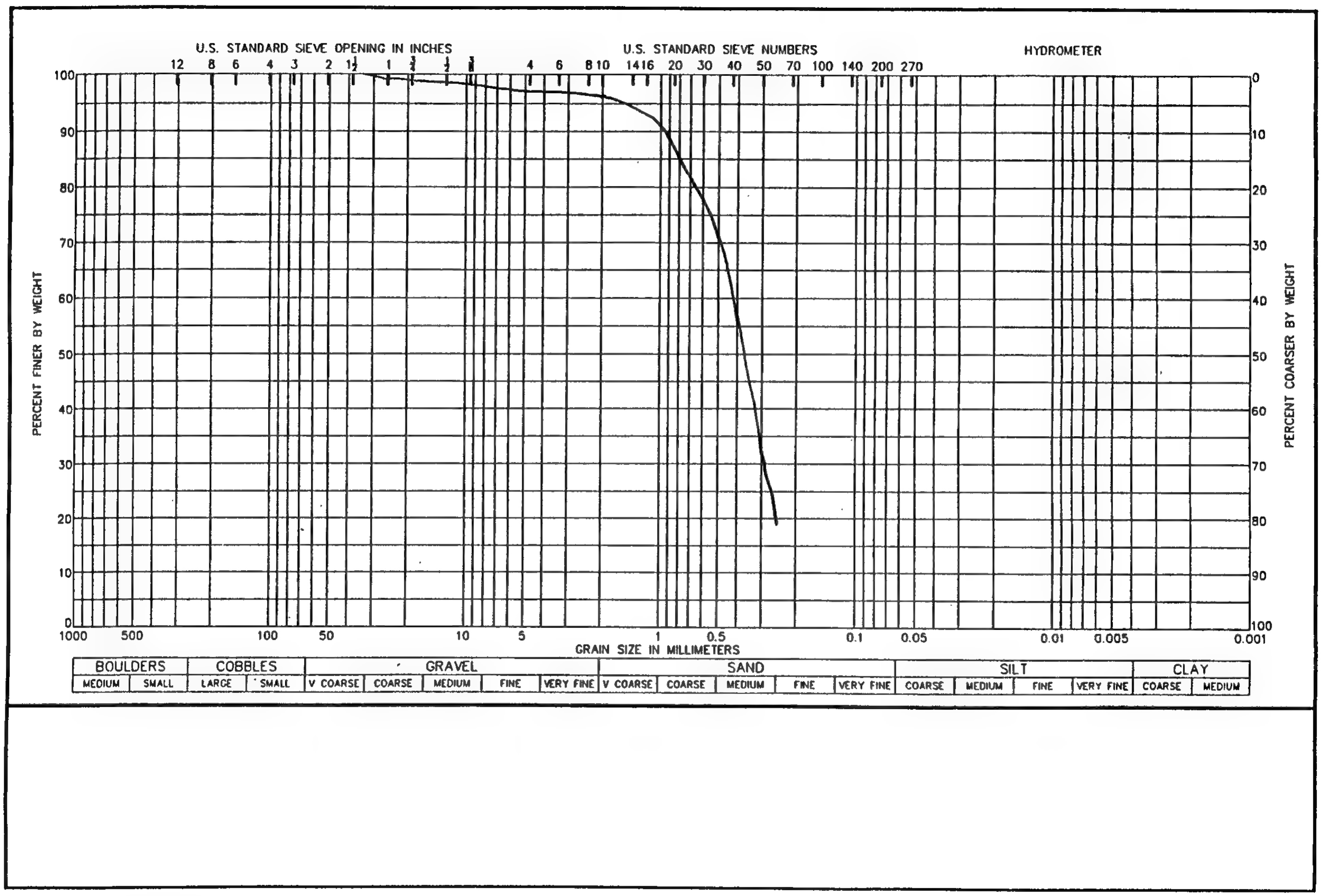


Figure 31. Bed gradation, San Juan River

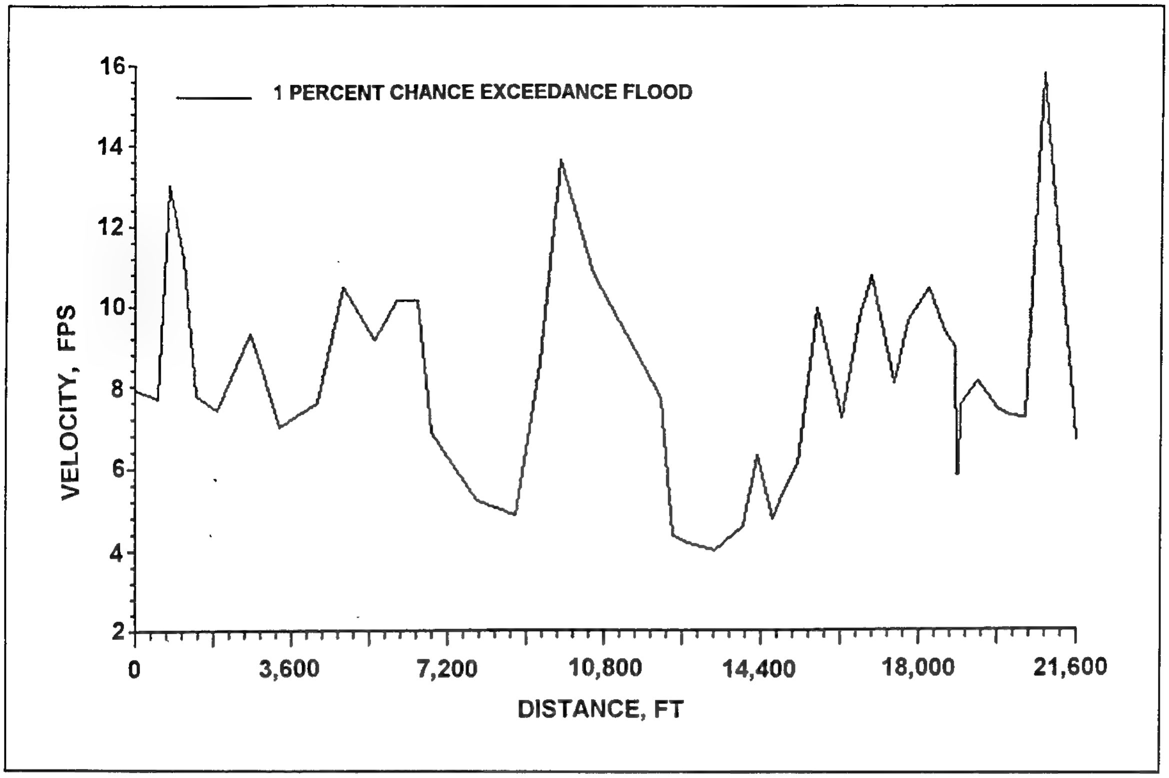


Figure 32. Channel velocity from HEC-2 model, San Juan River

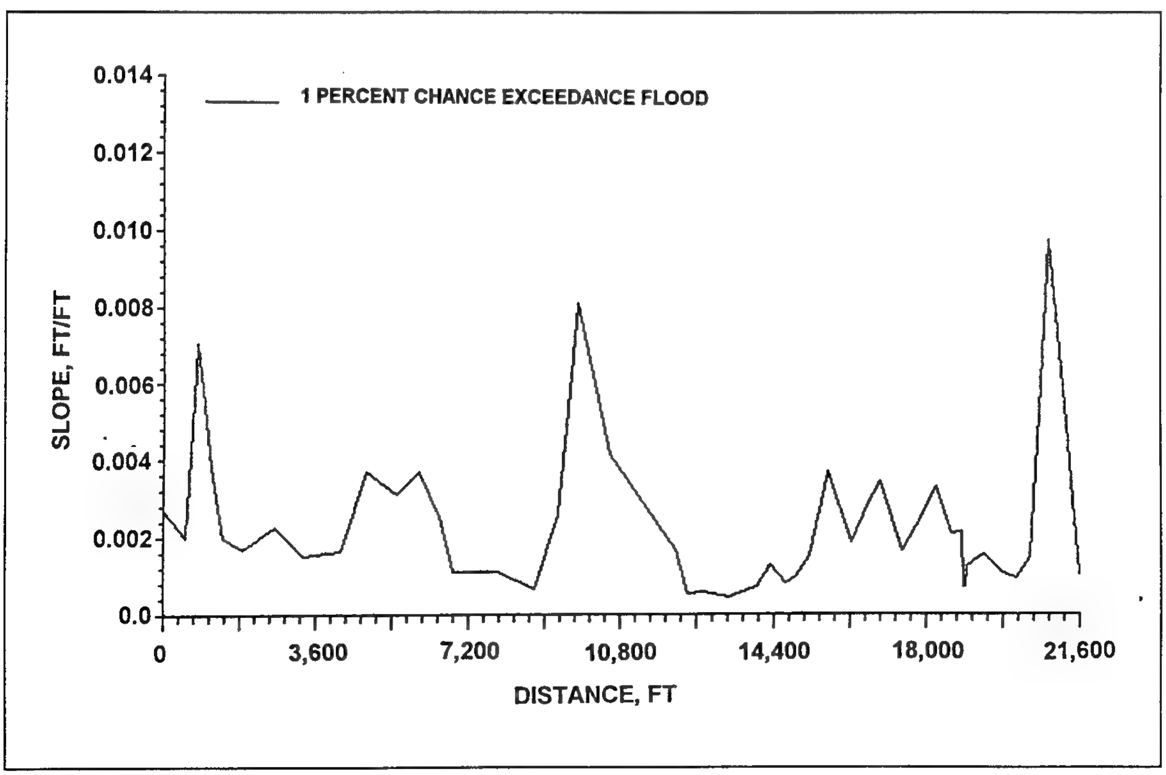


Figure 33. Slope from HEC-2 model, San Juan River

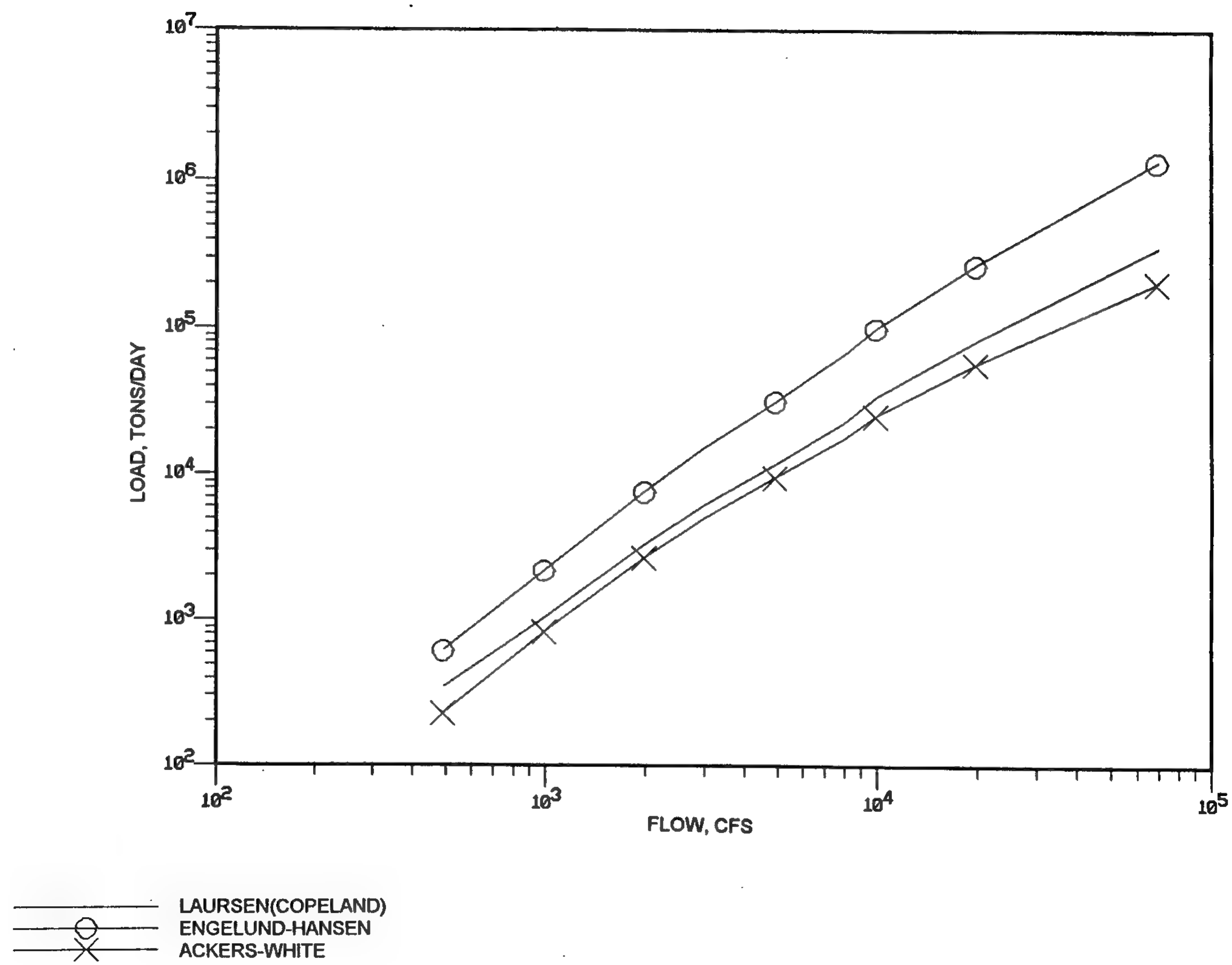


Figure 34. Sediment transport rating curves for material greater than 0.25 mm, San Juan River

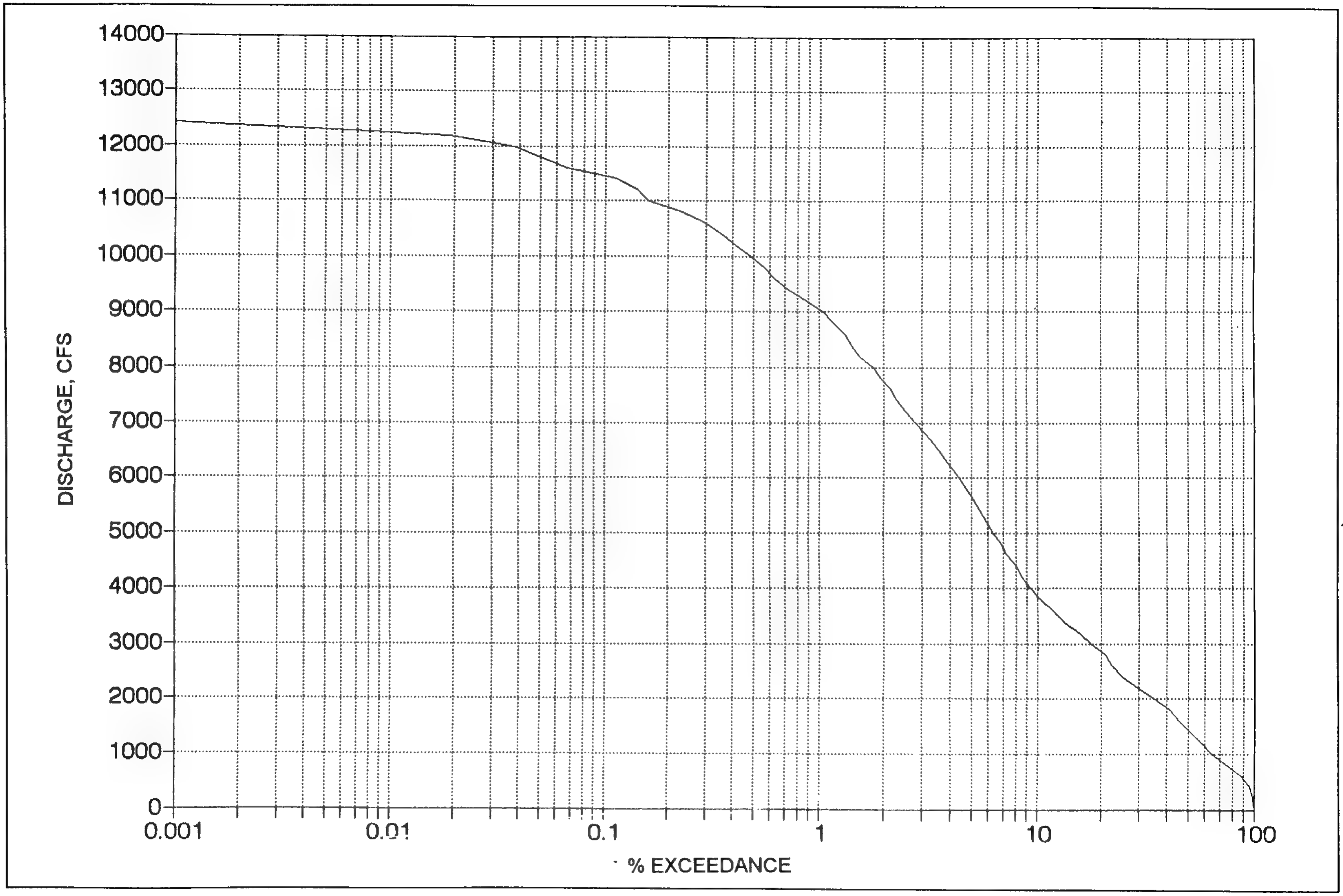
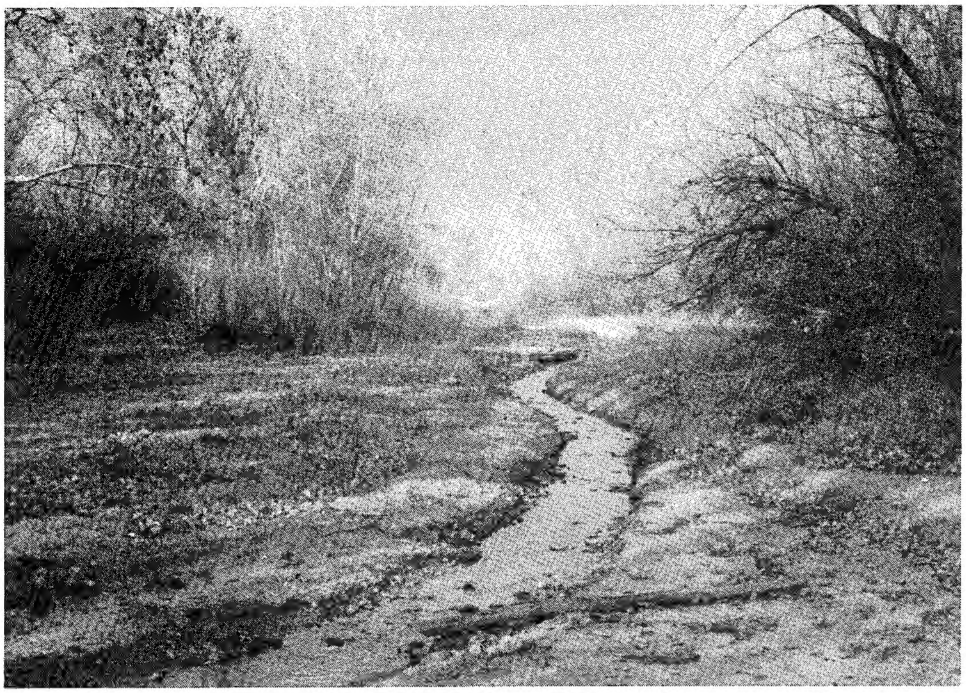


Figure 35. Flow-duration curve, San Juan River



a. Two sites, from the low-flow channel and the bar, both upstream of Glade Hills Drive

b. From the supply reach

Figure 36. Bed-material sample sites, Farmington Glade

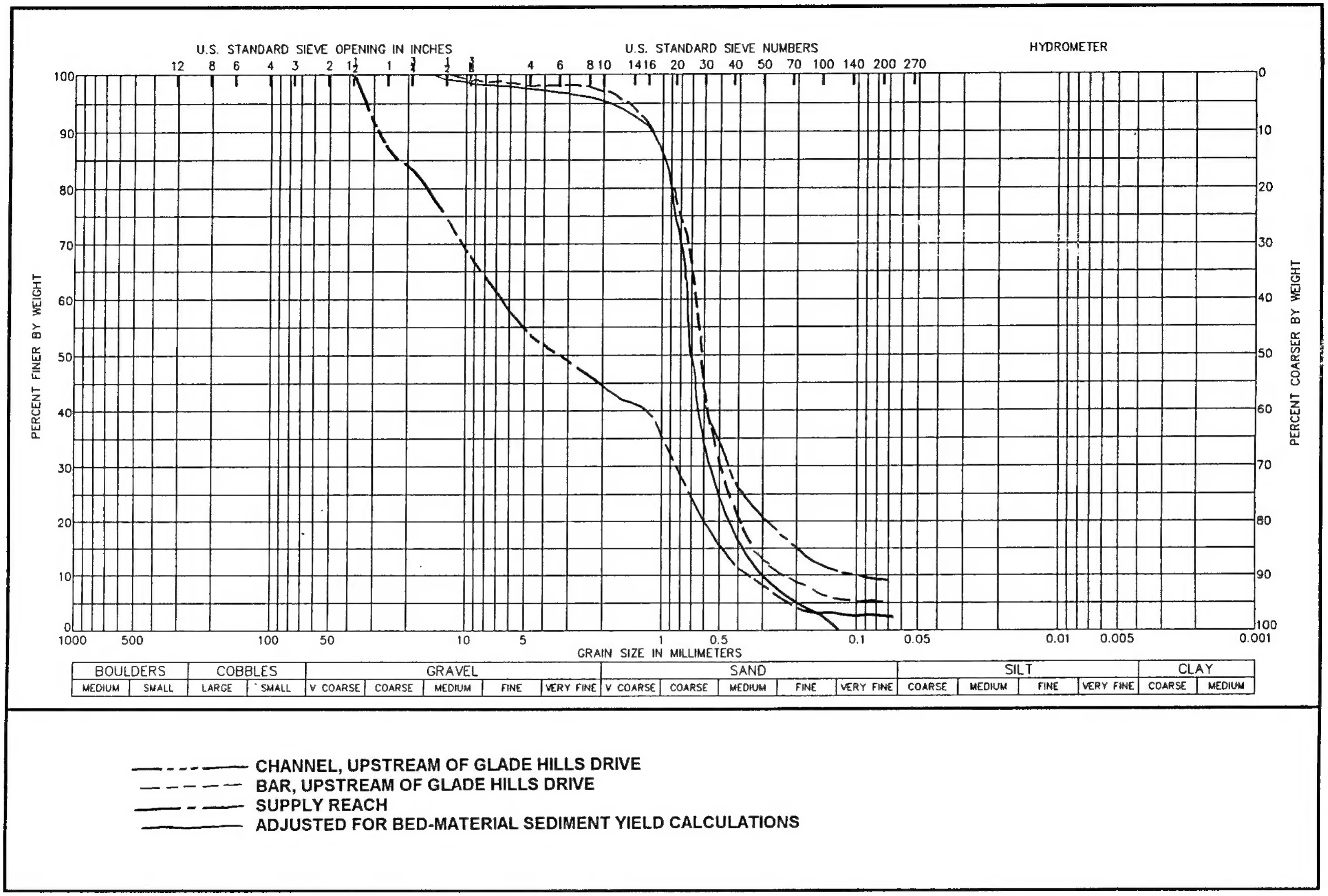


Figure 37. Bed gradations, Farmington Glade

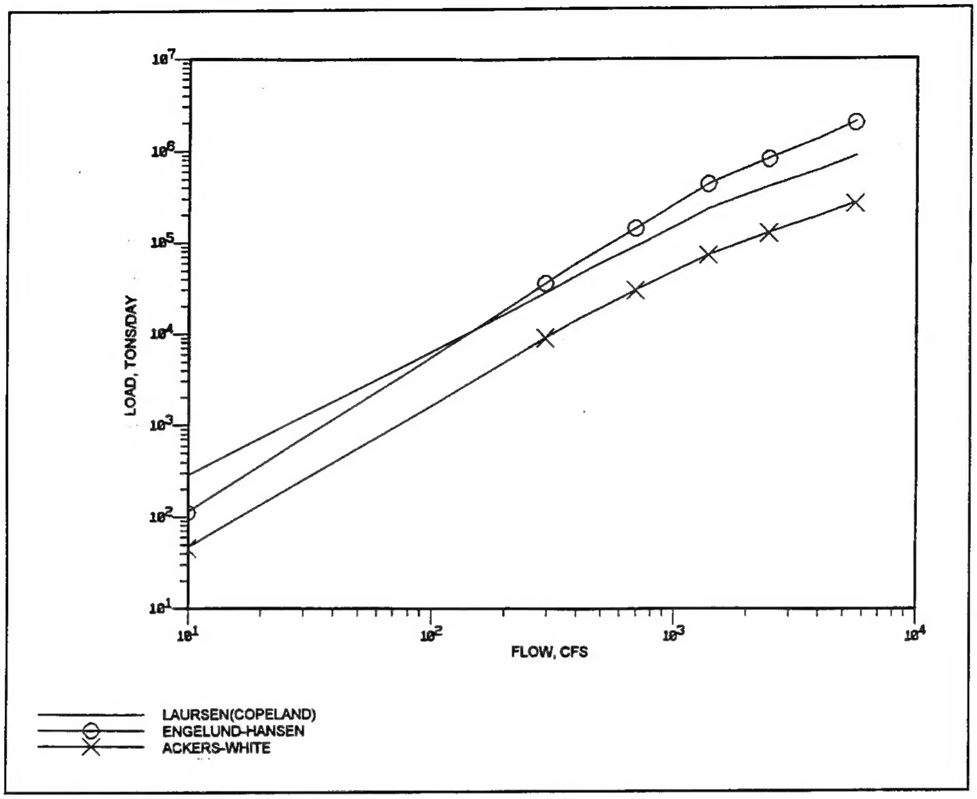


Figure 38. Sediment transport rating curves for material greater than 0.25 mm, Farmington Glade

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13. ABSTRACT *(Maximum 200 words)*

A sediment impact assessment was conducted for the San Juan River and tributaries, near Farmington, New Mexico, as part of a reconnaissance-level planning study. The purpose of the study was to evaluate each of four rivers' current conditions, to identify the magnitude of sediment problems associated with proposed flood control projects, and to recommend appropriate sediment studies for the fesibility-level planning study. The study employs the sediment budget approach to assess channel stability in the study reach. Total sediment yield estimates were made for determining potential aggradation and degradation zones. Recommendations for more detailed sediment studies were made.

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Sediment yield	Sedimentation

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